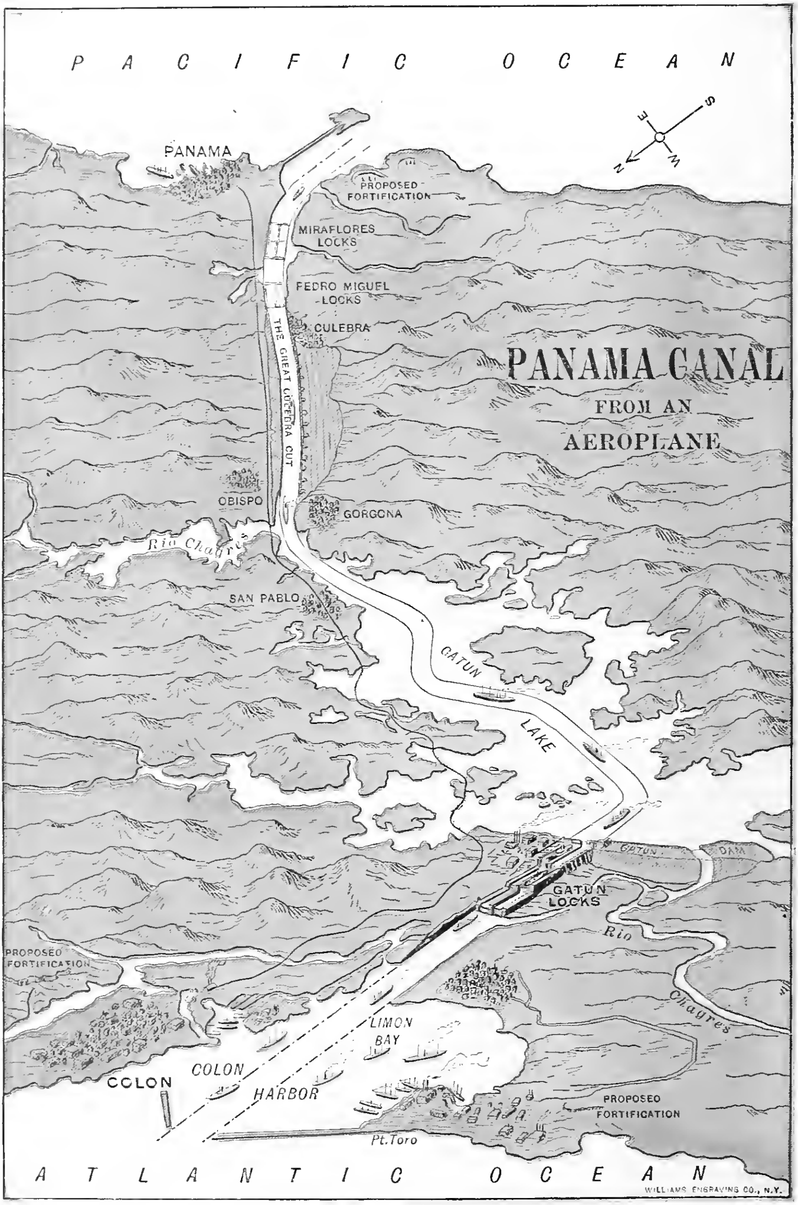
A BRIEF PHYSICAL GEOGRAPHY

JOHN W. DAVIS
THOMAS H. HUGHES



How Man Changes his Environment

A BRIEF PHYSICAL GEOGRAPHY

BY

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HINDS, NOBLE & ELDREDGE, Publishers
30 Irving Place New York City

PREFACE

The authors hope that this book will be welcomed in those schools in which the time is lacking to master the bulky books on Physical Geography, while yet the desire exists to devote to the subject somewhat more of endeavor than is required by the few pages on this subject found in the average school-geography.

Geography is considered to-day as a description of the earth only in so far as that will account for the earth as the home of man and his occupations. It seems as if we can no longer justify a purely physical geography; now we want to know **how** man lives and **why** he lives in this or that way. The most important fact about the earth is that it is a human planet: men not only **live** upon it but also **make a living** out of it. Man **changes** the earth, and the earth **changes** man. It is a far cry from the nebulous mass that was thrown off from the sun ages ago, to a contemplated aeroplane flight across the Atlantic or the completion of the Panama canal; but these are the limits of geographical study, and we have to bear in mind always that man is himself **a part of nature.** In the usual division of the study into physical, commercial, and political branches, the relation of the human species to its natural environment, which is the keystone of all geographical science, is generally lost.

In this volume, reference has been made, wherever possible, to the human side of natural phenomena, to their help or hindrance to man in his progress. The treatment of many points has been kept suggestive rather than exhaustive, since, in the tracing of causal relations, the geography of this grade lends itself so readily to the development of the reasoning powers of pupils. Among these relations are, for example, **altitude** and **temperature, weather** and habits of daily life, **mountain trend** and **rainfall, heat belts, winds** and **rain, topography** and **drainage, climate** and **vegetation**, and the **dependence of man on his physical environment.** The physical features of the earth may also be used to develop or interpret human industries, mode of life, dress, and other human characteristics.

Various features of the earth and the solar system, which affect the life of man only indirectly, have been treated in this book. Misconceptions of the most simple facts about the earth's crust are always with us. And though the only " practical " reason for studying the moon, for example, is the effect of this planet on the earth's tides, yet there are many simple astronomical facts that it may rightly be considered *"a disgrace and a misfortune not to know."*

The illustrations are intended to serve as the basis for class discussions and questioning, and it is hoped that they will be studied and interpreted with the text. The questions and exercises are designed to **promote thought.** The unit map idea has been employed, and particular attention has been given to the rigid *exclusion of irrelevant matter* from the maps. All rational work in general geography must be founded on physiography: the fact that the pupil is about to enter upon a general geographical review in the 8B Grade has been kept in mind in the preparation of the closing chapters.

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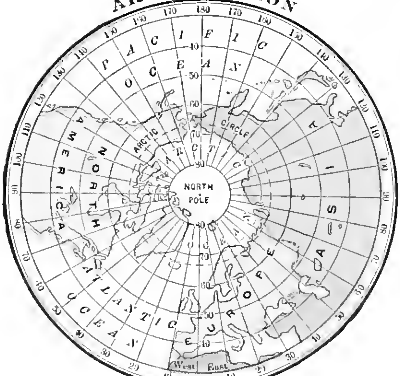
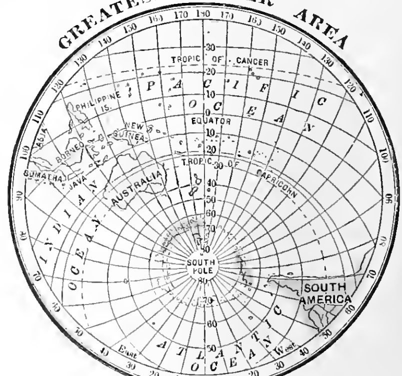
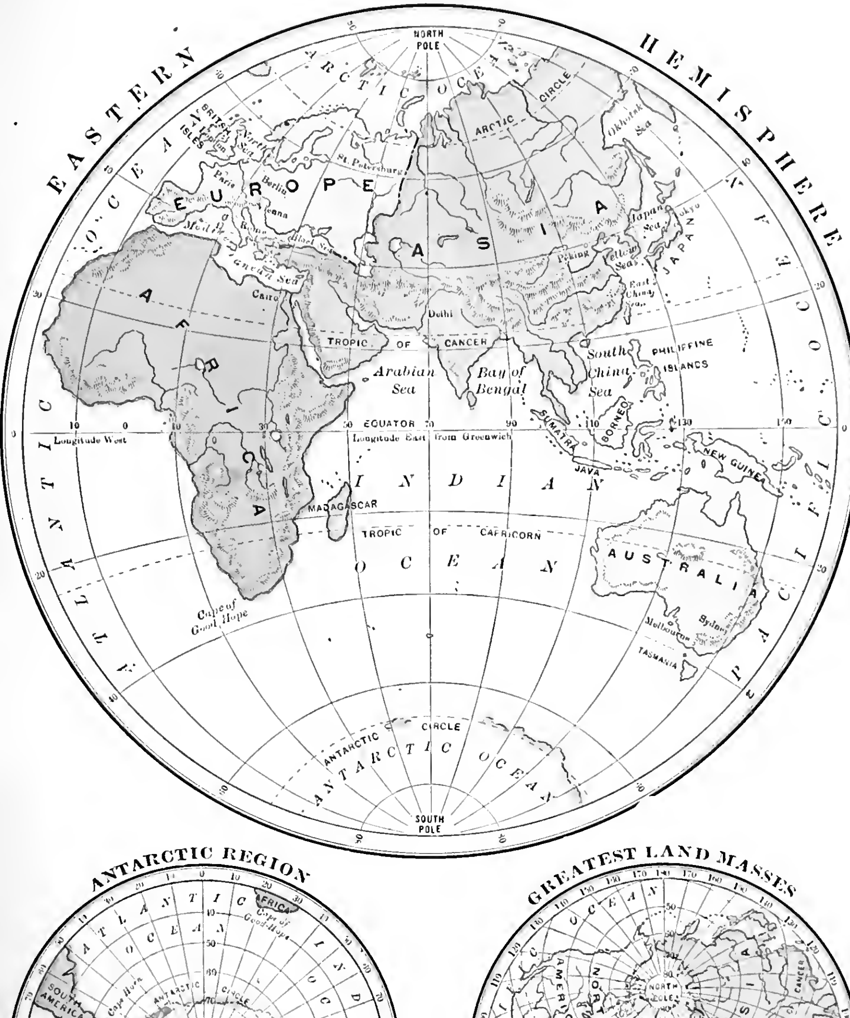
WESTERN HEMISPHERE

ARCTIC REGION



GREATEST WATER AREA

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Vienna
Rome
Black Sea
Cairo
Okhotsk Sea
Japan Sea
Tokyo
JAPAN
Peking
Yellow Sea
East China Sea
Delhi
TROPIC OF CANCER
Arabian Sea
Bay of Bengal
South China Sea
PHILIPPINE ISLANDS
SUMATRA
BORNEO
JAVA
NEW GUINEA
EQUATOR
Longitude West
Longitude East from Greenwich
INDIAN OCEAN
MADAGASCAR
TROPIC OF CAPRICORN
AUSTRALIA
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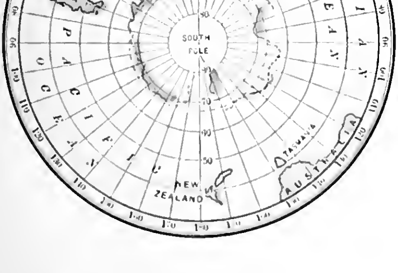
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TASMANIA
AUSTRALIA
NEW ZEALAND


GREATEST LAND MASSES
PACIFIC OCEAN
NORTH AMERICA
NORTH POLE
ASIA
EUROPE
ATLANTIC OCEAN
AFRICA
SOUTH AMERICA
INDIAN OCEAN
TROPIC OF CANCER
EQUATOR

CONTENTS

MAPS AND CHARTS

GEOGRAPHY

CHAPTER I

THE SUN AND THE SOLAR SYSTEM

The Stars. — Very few of us, if asked to tell the number of desks in our schoolroom or the number of aisles separating them, could do so without counting them; and yet we have been looking at these things every day since the beginning of the term. Neither could we tell the number of steps in the stoops of our houses up which we have run so many times. In the same way, we have neglected to observe carefully many of the great works of Nature that deserve our attention. For example, few of us have given very much attention to those twinkling lights in the skies that we call the stars.

FIG. 1. The Pole star with the Big and the Little Dipper.

A very wise writer once said that if these stars should appear only one night in a thousand years, every one would gaze up with wonder and would remember the sight forever. But, just because they do shine so patiently for us night after night, we persistently neglect them. Many of us, perhaps, have never imagined that some of these twink-

lings in that great space we call the sky may be other **worlds** greater than ours, making their own never-ending journeys.

Fixed Stars and Wanderers. — In order to learn a little more about them, it would be well for us to select a star on the next clear night and to get it on a line made with our eyes and the corner of the roof of any building that is between us and the star. We can mark with chalk the exact spot on which we stand when we get the star in line. Then make a similar observation for several other bright stars. When we return to these spots, several hours later, or the next night, and chalk-mark our position in line with the same stars, we shall see that our stars are no longer on the same straight line as before. The stars will appear to have moved slowly across the sky, most of them keeping together. But since the position of each one is *fixed,* in relation to the others, they are called **fixed stars.**

We can easily find the star group called the **Big Dipper** as shown in *Figures 1 and 2.* The stars marked "pointers" are so called because they seem to point to the **Pole star** which is always above the north pole of our earth. The Big Dipper moves with the other stars and once every twenty-four hours it revolves around the Pole star. The Pole star is stationary in the sky, and the group called the Little Dipper also moves around it.

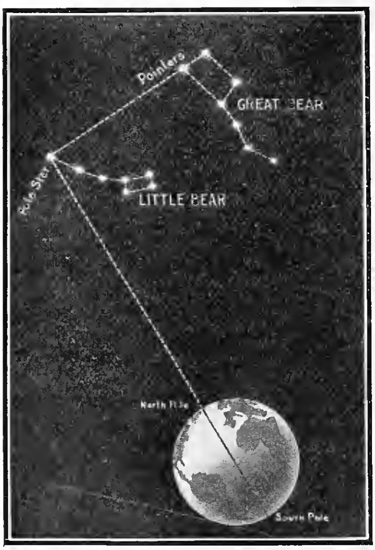


FIG. 2. Notice the pointers and the earth's axis, each in line with the Pole star.

There are some stars, however, that do not twinkle and that move from night to night at a different speed from that of the fixed stars we have been observing. They do not keep the same position in relation to the others but make great mysterious wanderings through space, always coming back, however, to the same position in which we first saw them. These stars are called **planets** (wanderers); our earth is one, and even the sun is one, because every morn-

ing during the year each appears among a different group of fixed stars.

The Sun's Family or the Solar System. — With the aid of great telescopes, astronomers have found that there are eight large planets revolving around our sun, and about five hundred smaller bodies, all making up a family that the sun supports with light and heat. *Figure 5* shows us that these move at different distances from the sun, along the paths called **orbits.** The planets have no light of their own, and little, if any, heat. Indeed, if they had, we should not be able to live on the earth. But we see them shining at night by reason of the sun's light reflected from their surface, as a mirror reflects the light of a lamp. All the members of the solar family resemble one another. They are spherical in form, and each one rotates on an axis of its own while revolving about the sun. The great difference between them is in their respective sizes and in the periods of time required for their revolution. We must always bear

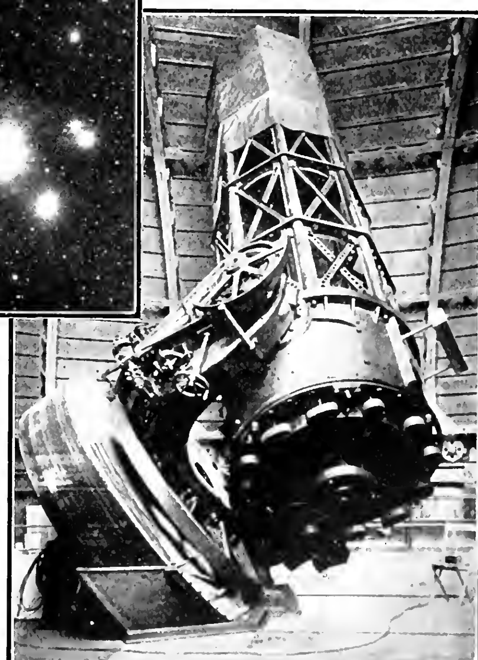


FIG. 3. The small picture shows the Dipper as seen through the Yerkes telescope. The other is the view obtained through the Mount Wilson telescope (FIG. 4), which is sixty inches in diameter.

in mind that from another planet in the sun's family our own earth would appear only as a dull star.

Names of the Planets. — Our earth is the fourth planet in size

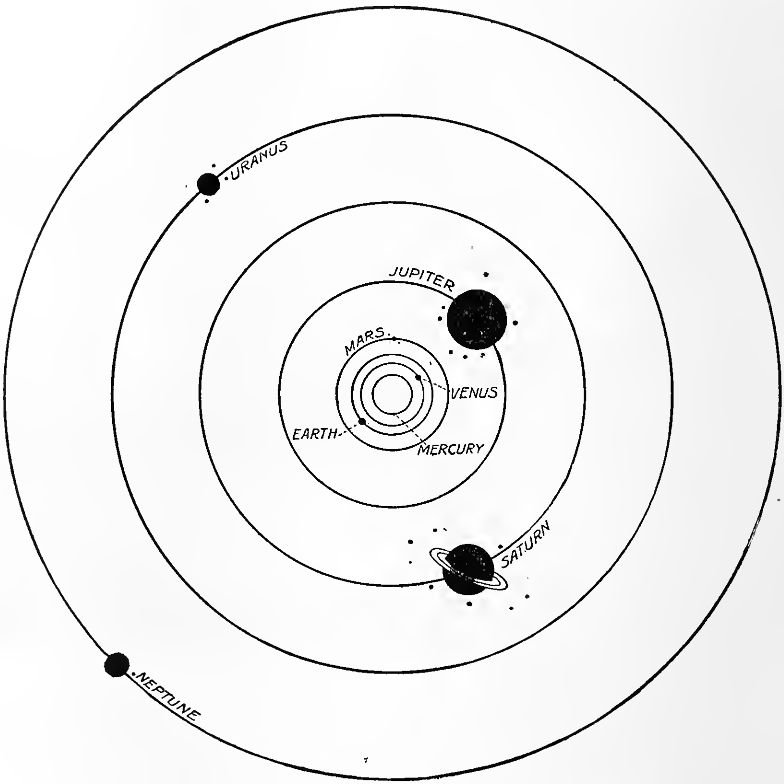


FIG. 5. The planets and their orbits in the solar system.

and the third in distance from the sun, requiring 365¼ days to complete its revolution. Nearer the sun is **Mercury,** named after the messenger of the Greek gods, completing its revolution in a year of 88 days. Between the earth and Mercury is **Venus,** the most brilliant of the planets. named after the goddess of beauty. Then in order come **Mars, Jupiter, Saturn, Uranus,** and **Neptune,** all of which have been likewise named after the Roman gods. Neptune and Uranus are so far away

from us that they cannot be seen without the aid of a telescope. All the others are easily observed, Venus, for example, appearing either as the Evening Star or the Morning Star, and Mars being recognized by its reddish tinge.

The nearer a planet is to the sun, the more rapid is its orbital movement and the shorter its year. For example, Venus, being a little nearer to the sun than the earth, completes its year in 225 days. (See Appendix 1.) Jupiter requires twelve of our years to travel once around the sun. Some of these planets are more distant from us than we are from the sun. Uranus, for example, is so far away from us that if an express train had started out from it 2,000 years ago to travel to our planet, even though it traveled sixty miles an hour, it would have completed to-day only a little more than one half its journey.

The Sun as the Source of Heat and Light. — We know that the sun, the central and largest member of the solar system, is a mighty power-house from which come all the forces that set in motion the earth and its life. We shall see that it is the sun's heat which causes the winds to blow, the clouds to ascend, the rivers to flow, the forests to grow, and man himself to live. We are familiar with the effects of over-exposing the skin to its rays, and we have seen how a lens can produce fire by concentrating upon one spot the rays spread over a circular space. And yet, just as this page now receives but a small part of all the light given out by an electric bulb, so the earth being so small a sphere in the sun's family gets but a tiny part ($\frac{1}{2,000,000,000}$) of the entire amount of energy given off by the sun. Let us imagine a great sheet of ice, ninety-eight feet thick, covering all the earth. If the quantity of heat received by the earth in a year were uniformly distributed, it would be sufficient to change this mass of ice to water in one year.

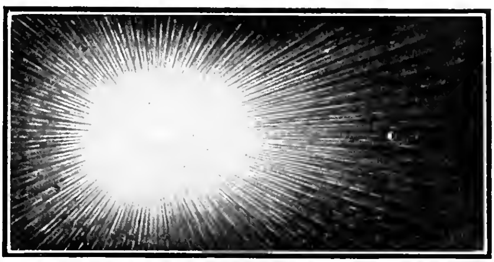


FIG. 6. The earth's tiny share of the sun's heat.

To attempt to measure the light of the sun by any of the means

at our disposal is a hopeless task. The light of countless millions of wax candles could not begin to give us an idea of the power of this wonderful star of day which, 92,750,000 miles away, sends us so small a fraction of its beams, yet accomplishes results so marvelous.

The Surface of the Sun. — We are never able to see the surface of the sun because great masses of burning gas surround it, very much like the burning vapor enveloping a sponge when we soak it in alcohol and ignite it. These fiery gases blaze up to incredible heights above its surface; for example, if the earth were ablaze as is the sun, the flames would soar high enough to reach our moon. The surface of the sun seems to be in violent commotion as if it were in constant eruption. Moreover, through great telescopes, we are able to observe peculiar patches on its surface. These spots are called sun-spots, which travel across its face and disappear on the opposite side. This movement takes place because the sun also rotates on its axis. We do not know just what these spots are, but we are sometimes able to trace their influence upon climatic conditions on our earth.

REVIEW QUESTIONS. — (1) Can you think of any use sailors might make of the Pole star? (2) Mention some ways in which the planets resemble one another. (3) Explain the difference between a fixed star and a planet. (4) What difference would there be in the appearance of the earth to an observer on Mercury and one on Jupiter? (5) What is the approximate number of days in each of our seasons? (6) Assuming that their axes are inclined at the same angle as that of our earth, give the approximate number of days in each of the seasons on Mercury, Mars, and Neptune. (See Appendix ii.) (7) Can you think of any other instrument than the lens which makes use of the sun's heat? Try to find out what a solar engine is and how it is used.

EXERCISES. — (1) Locate the Big Dipper in the sky and sketch it in your notebook. (2) Standing on the same spot at the same hour, draw this star group on three successive nights. Account for the differences in the diagrams. (3) Watch the appearance of the moon for six successive nights and report in class what you observed. (4) Cut from cardboard circular pieces to illustrate the relative sizes of the planets. (5) Since light travels 186,000 miles per second, how many minutes will it take for light leaving the sun to reach the earth? (6) Make a diagram of a lens concentrating the sun's rays at one spot. (7) Tell how the amount of heat we receive from the sun changes in the four seasons. Give all the results of these changes that you can think of. (8) Suppose the distance of the earth from the sun were 46,000,000 miles. What changes can you think of as taking place on the earth? (9) Suppose the earth were changed in position with Uranus, what differences might be expected? (10) Make a list of the planets in order of size; a list in order of distance from the sun.

The Origin of the Solar System. — Where did the earth come from? What is the moon we see at night? How do Mars and Jupiter

come to be journeying forever around the sun? Why is the planet Venus round? What force keeps Uranus at a distance of 1,800 million miles from the sun, permitting it neither to retreat another million miles nor to advance a thousand miles nearer? Why is that great abyss that contains the Pacific ocean on the earth? Where did the water come from that fills it?

Most of us have observed that when an automobile spins rapidly over a muddy street, the tires repeatedly cast off particles of mud. These particles fly off in the same direction as the wheel is traveling, and when we try to brush them from our coats, we observe that they are generally circular in form.

It is believed that millions of years ago all these bodies that we know as the sun's family existed not as separate units but as one great cloud or **nebula** filling all the space within the great orbit of Neptune. This enormous cloud of highly heated vapor, after a long period of time began to cool and to grow smaller in expanse. As it did this, it took on a rotary or spinning motion like that of a top, bulging out at the equator and flattening at the poles. Then, just as our automobile tire did, this great cloud began to throw off from its middle part, or equator, masses of fiery vapor in the form of rings. These ring masses of heavy cloud gradually took on a spherical shape and acquired their direction also from the whirling movement of the parent mass. Invisible lines of force permitted them to travel only a certain distance away from the central mass and then forced them to swing around in their orbits forever at that distance.

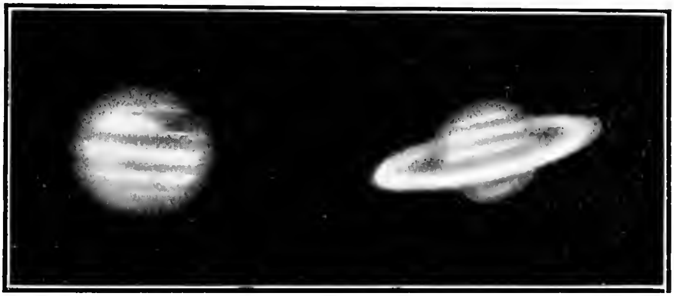


FIG. 7. The planet Jupiter. FIG. 8. The ringed planet Saturn.

In this way, we suppose the eight great planets flaming with heat were thrown off from the sun and have ever since been revolving around it. Immediately these great rings of vapor themselves began to cool

and contract, while keeping up their whirling motion. Then, just as the sun did, many of them threw off smaller rings. The best type of these smaller bodies is our own moon, which we believe was cast off from the earth. Astronomers find that the size or volume of the moon is about the same as that of the great gash in the earth's surface that we call the bed of the Pacific ocean, and they suggest that perhaps the moon-mass originally filled that depression.

Figure 7 shows that the great planet Jupiter is still so hot that its atmosphere is filled with clouds of steam, while *Figure 8* indicates that Saturn is in the process of throwing off rings of vapor which may become moons to circle about the parent body.

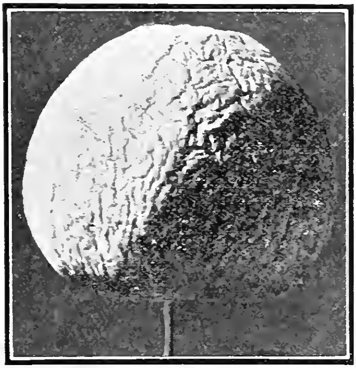


Fig. 9. The effect on an apple of heating and cooling.

We all know, despite the care with which a cook smooths over the covering of an apple pie before she puts it into an oven to bake, that this crust, in the process of cooling and recovering from the abnormal swelling produced by the oven's heat, will crack and wrinkle and pit. The crust has become too large for the pie and must lie in folds or wrinkles to fit the plate. In just the same way the great planets, after millions of years, began to cool on the outer parts; and this crust, shrinking after the terrific heat, produced all the irregularities that on the earth we know as continents, sea-bottoms, mountains, and valleys. You know that when steam from the spout of a kettle strikes a cold window-pane the vapor becomes liquid, which you see on the glass. In a similar way, as the space about these cooling planets grew colder, the steam surrounding them also cooled and became liquid, at one time covering all the surface of such planet; then, as the irregularities in the crust were formed, the water flowed into the deep places and produced the oceans.

Satellites, Comets, and Meteors. — Most of the stars that we see at night are not members of our solar system but are fiery bodies like our sun, with their own systems of planets. They are so far away that they appear only as twinkling lights. We can realize

the wonderful size of the universe when we reflect that some of these great suns are so distant that the rays of their light which are now reaching our eyes, must have started over two thousand years ago on their journey to the earth.

There are other members of our solar system which are not planets, but the results or outcome of the rings of vapor cast off by the planets. These are called **moons or satellites** ("guardians"). They shine by light reflected from the sun and revolve about their parent planets in the same direction as do the respective planets around the sun. Mercury and Venus are the only planets whose satellites are not to be seen. *Figure 5* shows the moons of the other planets.

Comets are fiery bodies which revolve about the sun in very elongated orbits and some of them come near enough to the earth to be visible to us. The **mass or "head"** of these mysterious travelers is always very small, but, in the form of vapor in the sky, the size appears enormous. Since they travel with great speed, this cloud-like mass trails out into a "tail" behind them, often thousands of miles in length. The tail follows the head when they approach the sun but streams out in front of the head as they retreat from the sun. In 1759 Edmund Halley, an English astronomer, predicted the appearance of a comet because he had traced out its orbit around the sun. This traveler, now called Halley's comet, comes inside our solar system and circles around the sun once every seventy-five years. It made its last appearance, as shown in *Figure 11*, in 1910 and will be due again in 1985.

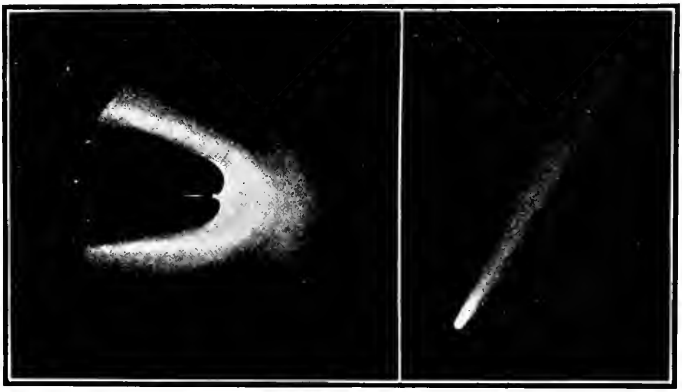


Fig. 10. The comet of 1861 retreating from the sun. Fig. 11. Halley's comet approaching the sun.

Meteors. — Everybody has at some time beheld the strange sight known as falling stars or shooting stars or **meteors.** On any clear night a few of these can be seen darting across the sky. They are supposed to be very small, solid bodies, perhaps but a fraction of an ounce in weight, which plunge through our atmosphere with such speed that they are set afire and consumed by the heat of friction, developed when they strike our atmosphere. Other meteoric bodies of larger mass, called **meteorites,** are not entirely consumed and often fall upon our earth. These are found to be of stone or iron, the largest fragment ever seen to fall weighing about a quarter of a ton. We know very little about the origin of these bodies. Some people suggest that they have been shot out of the sun or that they were cast into space by volcanoes on the surface of the moon.

Am. Mus. Nat. Hist.

FIG. 12. The Cape York meteorite which weighs 36.5 tons.

Earth the Home of Man. — In this wonderful way was the earth created by a Divine Master who waited millions of years for it to shape and prepare itself before he placed upon it his greatest creation, Man. It is our work now to learn more facts about our own planet as it revolves in space, to learn what other conditions Man has to meet on it, and then to see how he succeeds in making it a better home by mastering one after another the forces of nature in action upon it, how he changes the land, makes use of the waters, and attempts the conquest of the air.

REVIEW QUESTIONS. — (1) What is the importance of the sun in the solar system? (2) Make a sketch of a wagon-wheel revolving swiftly in a muddy road. What does this illustrate about the formation of the solar system? (3) If some of the fixed stars are great suns like our own, how is it they appear so small? (4) What is the difference between a satellite and a planet? (5) Tell the difference between a comet and a meteor. (6) A scientist has declared that if Halley's comet were compressed, it could be contained in a tea cup. What does this indicate about the substance of which a comet is composed? (7) What might be the result if a comet struck our earth? (8) How is it that we do not

see the moon clearly in the day time? (9) How would the appearance of the sun change to a person who might be imagined approaching it on a comet?

EXERCISES. — (1) Write in a paragraph an explanation of the way in which we suppose the planets were formed. (2) Secure a smooth apple and place it in a hot oven until it is baked. Bring it to class and explain the appearance of its skin. What does this illustrate about the earth? (3) Describe the appearance of the earth as it would be if the vapor around it had never been cooled into moisture. (4) Make sketches showing the appearance of a comet approaching the sun and retreating from it. (5) Make a drawing showing Mars, Venus, and the earth in their orbits.

CHAPTER II

THE EARTH AS A PLANET

The Earth in Space. — In learning how the earth is fitted to be the home of man, we have seen that it is a great sphere supposed to have been cast off from the sun millions of years ago. It is now whirling through space at the rate of a thousand miles a minute, or more than one and one half million miles per day, in a never-ending journey around the sun. This movement is called the planet's **revolution.**

The Size and Shape of the Earth. — As a result of its rapid turning when a molten mass, it began to flatten at the north and south

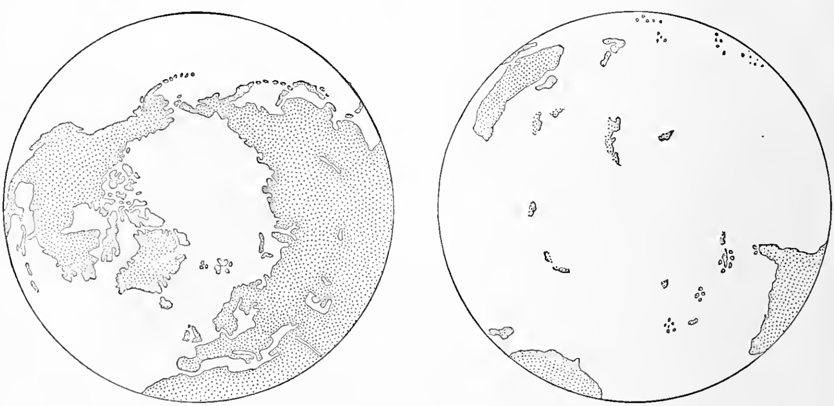


FIG. 13. The land and the water hemispheres.

poles so that now it is hardly a perfect sphere but resembles an orange in shape. Such a body is called an **oblate spheroid;** and a line connecting the two poles is about twenty-six miles shorter than a diameter through the earth at the equator. A polar diameter is about eight thousand miles in length and our planet is nearly twenty-five thousand miles in circumference. It would take an express train,

moving a mile a minute, seventeen days and nights of continuous travel to complete the journey around it.

We can see from *Figure 13* that the water which formed when the earth was cooling now occupies seven tenths of its surface, the remainder being occupied by the continents and islands. The larger part of the land area is in the northern hemisphere which includes almost all the large continents. The southern hemisphere is practically a water hemisphere. The center of the land hemisphere is near the city of London while the opposite end of an axis driven through the earth at this point is the center of the water hemisphere. This point is near New Zealand.

The Spheres or Layers of the Earth. — We know very little about the central body or core of the earth. We believe that it is still a glowing hot mass of nickel-iron under great pressure. This ball is called the **Centersphere** of the earth. Pressing in on this portion is the crust of the planet, some twenty miles in thickness, that we call the **Rocksphere.** Where this crust is irregular and depressed the great **Hydrosphere,** or watersphere, fills the cavities. We believe that, ages ago, this water envelope covered the whole earth, until the great gaps we call the ocean beds were formed and then the water ran into them. As the crust sank in some places, when the centersphere cooled and contracted, it was distorted into folds and wrinkles. It is these great upfolds that form the continents, lifting themselves above the hydrosphere of the planet. On these continents the crust was forced into narrower folds forming mountain ranges and, during the rising of these, the rocksphere was often broken and folded. Through the cracks in the crust, formed in this way, molten rock sometimes came forth in great quantities such as to build the peaks and cones we call volcanoes. The crust of the earth is still changing; and the rising of the land has often been accompanied by earthquake shocks caused by the breaking and slipping of the layers of material in the rocksphere, as they moved one upon the

Fig. 14. A section of part of the earth.

other. Finally, enclosing both land and water in a great sea of air, at the bottom of which we move about, is the earth's **Atmosphere.** This belt of air extends about forty miles from the planet in all directions but the greater part of the air is near the earth's surface.

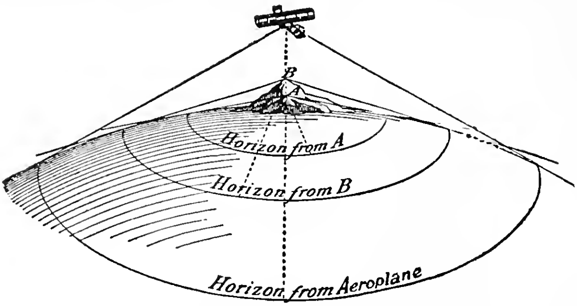


Fig. 15. The broadening horizon seen from different elevations.

Proofs of the Earth's Shape. — A fly crawling over a circular lamp shade can see but very little of its surface at any one moment, and that very little must appear flat to the insect. In much the same way our earth, really spherical, appears flat to us looking along its surface, so that we can easily understand to-day the fear of the ancients in venturing out of sight of land.

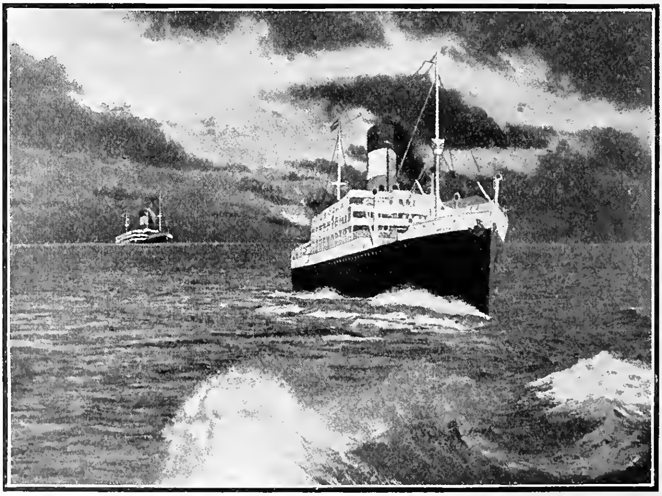


Fig. 16. Steamer entering port.

We all know that when we look out from the windows of the first story of our school building we can see more of the street than we can from the ground; and if we mount to the roof we can see the roofs of many houses below us and the surfaces of many streets. If we

could go farther up in an aeroplane, we might see the whole network of streets that make up our city. However, our range of vision would always be bounded by the curved line, where earth and sky seem to meet, that is called the **horizon**.

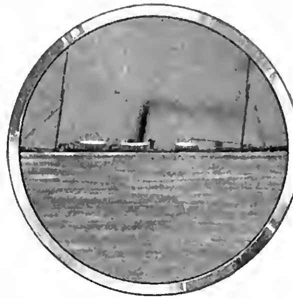


FIG. 17. A view of a distant ship as seen through a telescope.

This horizon seems both to enlarge and to sink as we ascend above the surface; whereas, if the earth were a flat surface, our field of vision would not change, no matter how high we mounted. The horizon is always circular, which would not be the case if the earth's form were not very nearly spherical.

Suppose you were in positions A and B in *Figure 15*. How would your observations prove the shape of the earth? A ship leaving port drops over the horizon line and disappears from our view because of the earth's spherical curvature. How do the steamers in *Figure 16* prove this? *Figure 17* shows a view of a steamer obtained through the glasses of a marine telescope. Explain why the vessel should have this appearance.

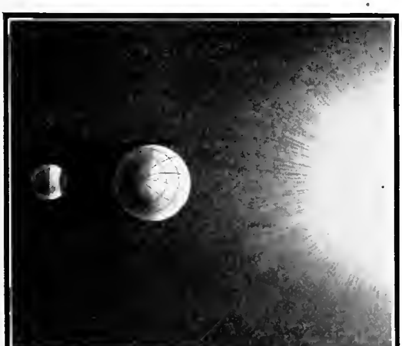


FIG. 18. The circular shadow of the earth thrown on the moon.

Hold an orange in front of a lamp and observe its shadow on a piece of paper. Sometimes the earth has the position of that orange when the planet is between the sun and the moon. How can the appearance of its shadow (*Figure 18*) be used as a proof of the shape of our planet?

Poles; Axis; Equator. — We know that this planet turns or rotates on its axis once in twenty-four hours, and that it moves through space revolving around the sun in a fixed orbit once in every year of $365\frac{1}{4}$ days. At the ends of the earth's axis are the **poles,** the **north pole** being the one above which the Pole star, far out beyond us in space, seems to twinkle. (See *Figure 2*.)

As the earth turns, its axis does not keep a position straight up and down but it is inclined to the plane of the orbit in which it moves as shown in *Figure 20*. This angle of inclination from the perpendicular is $23\frac{1}{2}$ degrees. So that as the earth moves about the sun, the north pole first leans away from the sun. When the planet has reached the other side of the sun, the north pole leans toward the sun.

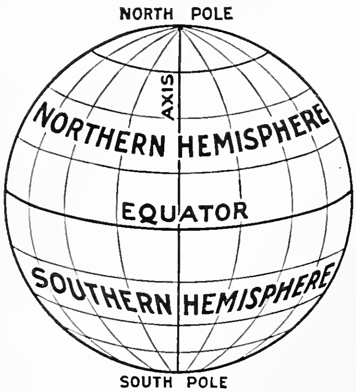


FIG. 19.

We know the equator to be an imaginary line half way between the poles, dividing the sphere into the northern and southern hemispheres. All the places along the equator have a faster rotary motion than any other part of the world — a thousand miles an hour. They correspond really to the points around the rim of a wagon-wheel which swing around rapidly when the wheel is in motion while all parts of the spokes toward the hub move at a slower rate, till at the hub of the wheel the motion is very slight. What then is the extent of the rotary movement at the poles of the earth?

Gravity and Gravitation. — When you drop a lead pencil it is drawn not to the right nor to the left nor does it move upward to the ceiling, but it falls as far as it can toward the center of the earth. When a leaf falls in Siam, opposite us on the globe, it too is drawn to the center. Should the engine of an aeroplane miles above the surface be shut off, the machine glides always down to the earth, and not off to Venus. There is a force coming from the center of our planet which attracts every atom of matter to it and holds it in place. This force is **gravity.** Without it we would be swept from the earth when it rotates at such terrific speed, the waters of the sea would be dashed from its surface, and your lead pencil would fly up instead of being drawn down!

How can it be, moreover, that the earth revolving at the speed of one thousand miles a minute does not fly off from its orbit and away into space? Why does our faithful satellite, the moon, attend

upon the earth so steadily and never dash off to another planet? What power holds Mars and Uranus whirling round and round the sun? To demonstrate this force we can place several blocks of wood, large and small, in a bathtub over night and observe their position the following morning.

In studying the solar system we said that invisible lines of force held the planets in their orbits just as a string holds in its orbit a stone you whirl about your body. This force, the attraction between two large bodies, we call **gravitation.** The onward sweep of the planets is really the result of two forces. The first is the centrifugal force which causes a planet to keep moving in a straight line and drives it away from the sun. The second force is gravitation which tends to draw the planet back to the sun and away from a straight line. As a result, the orbit of a planet becomes nearly circular around the sun, and the body keeps up its revolution forever.

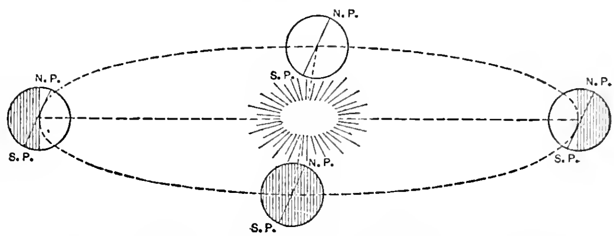


FIG. 20. Notice how the axis is inclined toward a line that is perpendicular to the plane of the orbit.

Gravitation differs from gravity because the latter is only the attraction of the earth for all bodies on it. The greater the difference in size between the bodies the greater is the force of gravitation. Hence the sun, over a million times larger than the earth, has little difficulty in controlling its motion. The same force holds the moon in its orbit around the earth.

REVIEW QUESTIONS. — (1) How far does the earth travel in its orbit in one hour? (2) Into what sphere of the earth does a volcano open when it is in eruption? (3) What proportion of the earth's diameter is crust? (4) If you were on a ship entering a harbor, would you see the base or the roofs of the high buildings first? Why? (5) Is the fact that Magellan sailed around the earth a proof that it is round? (6) Give three other proofs of the earth's shape. (7) Which diameter of the earth is longer, the equatorial or the polar? (8) Explain the difference between gravity and gravitation. (9) How high above the earth can an aeroplane rise? Why? (10) If an aeroplane should ascend vertically to a distance of two miles and then descend, would it return to the same point it left? (11) What differences might be observed if the earth lost its force of gravity?

(12) Show how our words **up, down,** and **level** depend on gravity for their meaning. (13) State some changes that might result in the western hemisphere if the ocean level were one thousand feet higher. Refer to *Figures 21 and 22.* (14) What changes might result if the ocean level fell one thousand feet.

EXERCISES. — (1) Make diagrams of a circle and an oblate spheroid. Compare the lengths of their axes. (2) Thrust a knitting needle through the stem end of an orange to the other side. By means of this show the two movements of the earth. (3) Write a paragraph giving an account of the way in which water came to be on the earth. (4) Draw two circles to scale and show the relative amount of land and water on the earth. (5) Take the orange in (2) and tilt it to show the inclination of the earth's axis. Now move it around a lamp. What do you observe about the position of the north pole? About the south pole's position? (6) Make a drawing to show the part of a steamer you would see first if you were on a high building in lower New York. (7) Draw the surface of the ocean as you would see it from this position. (8) Draw a circle to represent the earth. Place a dot for New York and draw a line to represent all the places in the northern hemisphere which rotate around the axis with the same speed as that city. (9) Make diagrams like *Figure 20* showing what the earth's position would be if the angles of inclination of the axis were $33\frac{1}{3}°$; $45°$; $90°$; $0°$.

CHAPTER III

THE CRUST OF THE EARTH

The Restless Surface. — We have seen that as the cooling earth shrinks, its crust wrinkles, rising in some parts and settling in others. This has left its crust far from regular. In some places mountains rise $5\frac{1}{2}$ miles above the sea level, in others sea valleys drop down $5\frac{1}{2}$ miles. The Japan islands, the Philippines, and the West Indies are merely the tops of mountain ranges rising from great ocean depths. Peaks in the Andes are over 40,000 feet above the ocean floor at points just off the coast. The work of changing the face of the planet is never complete. The earth's surface is never at rest. It is always undergoing changes. Movements of the crust are constantly elevating or lowering the land, so that sea-bottoms have been raised to make continents, mountains have been formed, and lands have been lowered beneath the sea. Other forces are tearing away the surface, smoothing down the high places, and trying to fill up the great gaps. The weather crumbles rocks, and rivers carry the waste off to the sea, glaciers rip and tear the land while the forces of the ocean eat it away. This leveling down of the crust is called **erosion.** This great struggle between the earth's crust to raise the land and the other forces to level it goes on forever; as a result of it we have all the irregularities of the surface which man must struggle with and conquer one after another to make his home on this planet.

The Great Continents. — The real margin of the continents is beneath sea level, so that they are really uplifted blocks of crust generally surrounded by the waters which once covered them. The land extends off shore for several miles forming what are called **continental shelves.** Islands rising above these shelves like Great Britain are called **continental islands** to contrast them with **oceanic islands** that lie like those in the Pacific far from any land.

Fig. 21. Relief map of North America.

FIG. 22. Relief map of South America.

Fig. 23. Relief map of Africa.

Continents consist of great backbones and ribs of mountain systems connected by plains and plateaus built of rock fragments worn from the mountains. These are cut by rivers which form valleys and drain the land.

1. **North America.** — Mountain ranges give to the continents their outlines; for example, the Western highland, the Appalachian system, and an old range which ran westward from Labrador have

given to North America its triangular form. Waste torn from these mountains in past ages formed the great plains and plateaus. All the irregularities around the gulf of Mexico are due to mountain ranges continuing along the continental shelf, while the irregular coast

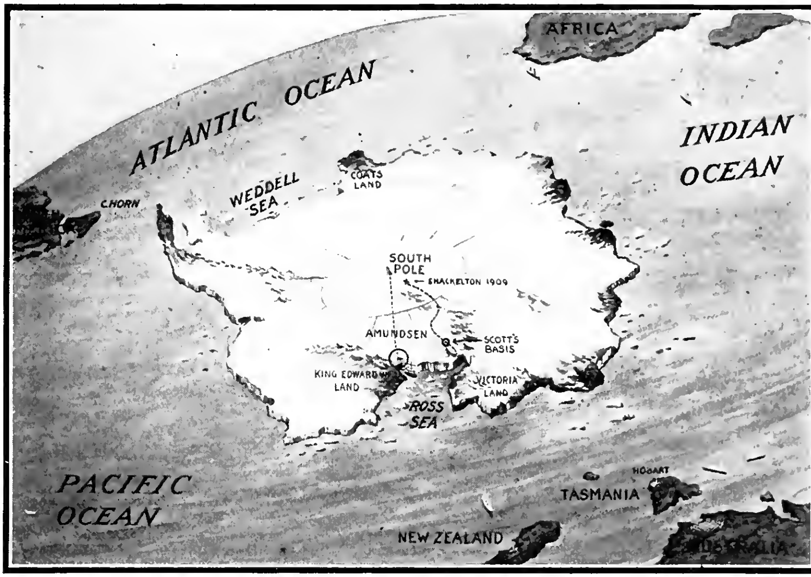
Fig. 24. Relief map of Australia and the East Indies.

line is due to the sinking of the land which permitted the sea to enter valleys. New York harbor, Long Island sound, Hudson bay, gulf of St. Lawrence, and all the peninsulas and islands were thus formed.

2. South America and Africa. — Observe how the mountains of these continents have determined their triangular forms. Since there has been no extensive sinking of the land except in the southern part, the South American outline is very regular. Mountain uplifts near the coast have made Africa mainly a broad plateau. The sinking has been very slight, hence there are few harbors.

Fig. 25. Relief map of Eurasia.

3. Australia. — Observe how the mountain chains failed to give this huge island a triangular form. Tasmania and York peninsula are merely continuations of the continental shelf, while the irregular coast line is due to the sinking of the continent.



Am. Mus. Nat. Hist.

FIG. 26. A view of Antarctica.

4. Eurasia. — Europe and Asia are really one continent, an irregular triangle in form, extending from Spain to Bering strait, and then down to Borneo. Its great peninsulas from Kamchatka around to Scandinavia are all due to the presence of mountains. Its great islands are the raised portion of the continental shelf. Its splendid commercial coast line is due to the sinking of the land which produced the Baltic, the North, and the Irish seas.

5. Antarctica. — This newly discovered continent apparently consists of a central plateau with sloping coastal plains. At one part a mountain range, with peaks 15,000 feet high, extends toward South America. Its size is about that of North America and its shape is

also triangular. An ice sheet of enormous thickness renders this continent unavailable for the purposes of man.

The Rocks of the Crust. — Almost everywhere on the land of these continents there is a layer of loose rock fragments, the sur-

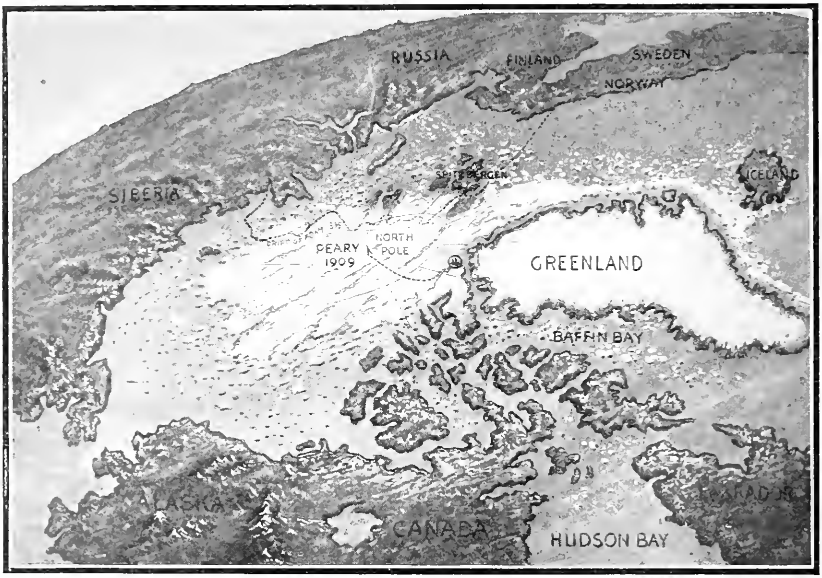


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Fig. 27. The top of the world.

face part of which is called **soil**; but wherever this soil coating is penetrated to a depth great enough, solid rock is found in great layers or **strata**. Mountains have no soil covering because the decayed rock falls away before the soil can accumulate. These strata of the rock-sphere are of many useful varieties, such as granite, sandstone, or limestone. In addition, the rocks contain layers of coal, beds of salt, and all the minerals of which man makes use.

Some rocks are very hard and others are soft; so that as the land is worn down by water, valleys are formed where the soft rocks give way, while hills and ridges stand out where the rocks have more resistance.

Weathering and Erosion. — The crumbling away of rocks is

called **weathering.** It is produced by the action of water, frost, and air, and through the efforts of plants and animals. Water dissolves

FIG. 28. Rock strata which have been tilted during the growth of mountains. Notice the work of erosion.

some of the minerals in rock and causes it to fall apart. In cold climates, moisture, penetrating the rocks, freezes in winter. When it freezes, it must expand, and in this way layers of rocks are often broken off by frost action. Air, warm in the day and cold at night, causes rocks to fall away by expanding them; again, the roots of

FIG. 29. The backbone of a continent.

plants often manage to split them. Earthworms, woodchucks, and other burrowing animals stir up the soil and permit water to enter rock more easily. This action of weathering results in the formation of soil from decayed rock; it causes landslides and avalanches on mountains; it makes valleys broader; and it roughens the appearance of rocks. In addition to the work of these agents of weathering, **erosion**, or the leveling of the land, is carried on by **winds** along the coasts and in deserts; by **rivers,** which carry off the waste caused by weathering; by the **ocean,** whose waves, tides, and currents attack the coast line; and by **glaciers,** which transport rock fragments for long distances. The force of **gravity** is also active here in drawing all the particles as far down to the earth's center as possible. By these forces, the continents would have been leveled down to the sea long ago, were it not for the movements of the crust which constantly lift plains, plateaus, and mountains still higher.

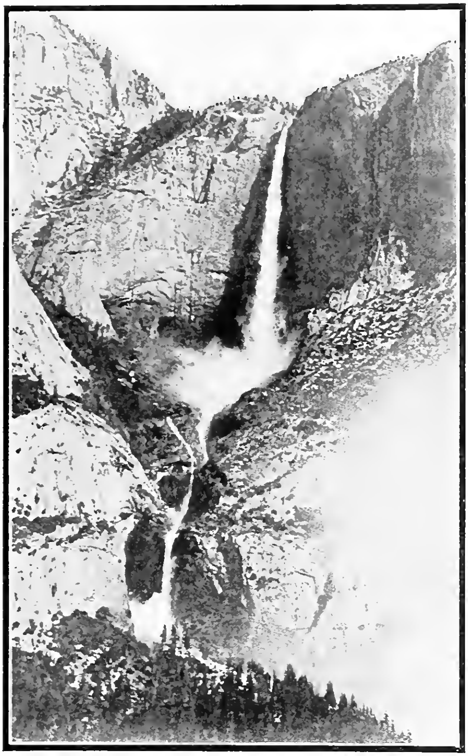


FIG. 30. A stream helping in the work of erosion.

QUESTIONS. — (1) How do mountains determine or affect the shape of continents? (2) What difference would follow in the form of North America and of South America if the ranges extended east and west? (3) Locate five continental and five oceanic islands. (4) What is the effect of the coast line on man's activities in a continent? Illustrate from Africa and North America. (5) Account for the irregular coast line of northern Europe; the scarcity of good harbors in South America; the British Isles; New York harbor; the eastern coast line of Asia. (6) Why are there so many irregularities in northeastern North America? (7) Explain the presence of southern California, Cuba, and

Porto Rico; Madagascar; Tasmania; Kamchatka; East Indies. (8) What is erosion? What is weathering? Name the forces which produce their effects. (9) What evidences have you seen at the seashore of the changes going on over the earth's surface? On a country road? In the mountains? In a city? (10) Tell about the effects of frost on the Palisades along the Hudson river.

The Work of Rivers. — Rivers aid in changing the surface of the land by carrying off the materials, or **detritus,** supplied by weathering and rain. The amount of sediment that they carry varies widely. Some rivers are clear, some are heavy and muddy. The detritus also varies from large boulders to gravel, sand, and clay. Every river carries some sediment, though it may be invisible. In addition to acting as carriers, rivers at some time in their history are busily at work cutting their channels. They not only cut their beds, but also eat away their banks and thus produce wide valleys. A stream rushing down a steep slope with great volume over soft rock will cut a deeper channel than a river which meets hard rock or one which is poorly fed with water. A river with little sediment, like the Niagara, cannot cut a valley as well as one with

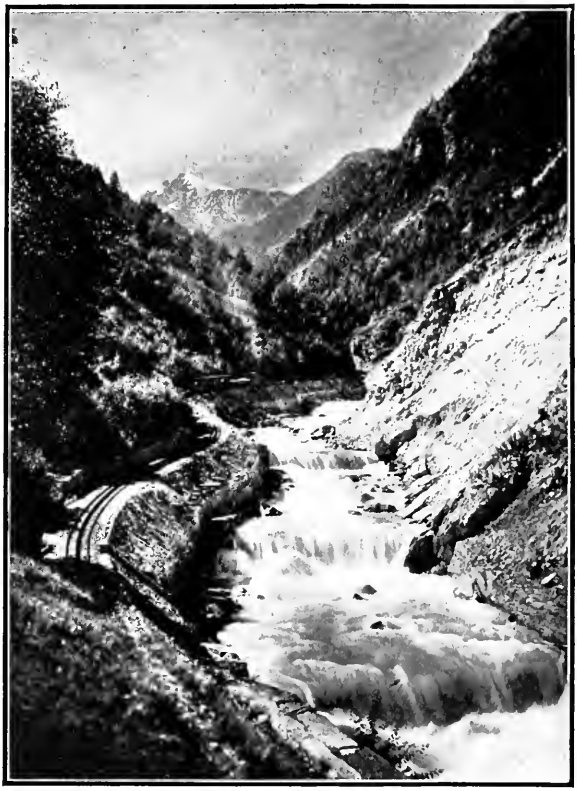


Fig. 31. A river cutting a gorge deeper.

a heavy load of detritus like the Colorado, which has cut an enormous canyon.

The **basin** of a great river is made up of all the land sloping toward it whose water and detritus reach the ocean through its efforts.

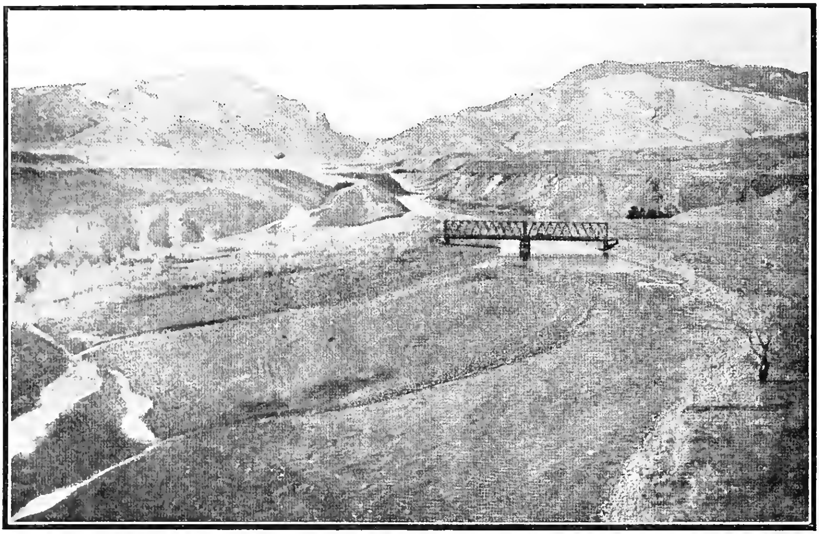


FIG. 32. A river during a dry period unable to carry off its load of detritus.

Minor streams which combine to feed the great river are called its **tributaries** and compose with it a river system. The elevated ridges running above continents which determine whether the rainfall of a slope is to feed into one river system or into another, are called **divides.** These separate river basins.

Young River Valleys. — A river's life work, then, is to wear away a great belt of land. When it begins this work, it is called a young river; and the valley it produces, narrow in proportion to its depth, is called a **young valley.** All **gorges, ravines, glens,** and **canyons** are young valleys. Men rarely settle in young valleys, because there are no gentle slopes adapted to agricultural purposes.

Sometimes a broad valley contracts for a short distance to a narrow chasm, because of a barrier of hard rock or a mountain ridge not yet worn away by the river. These short, young valleys are

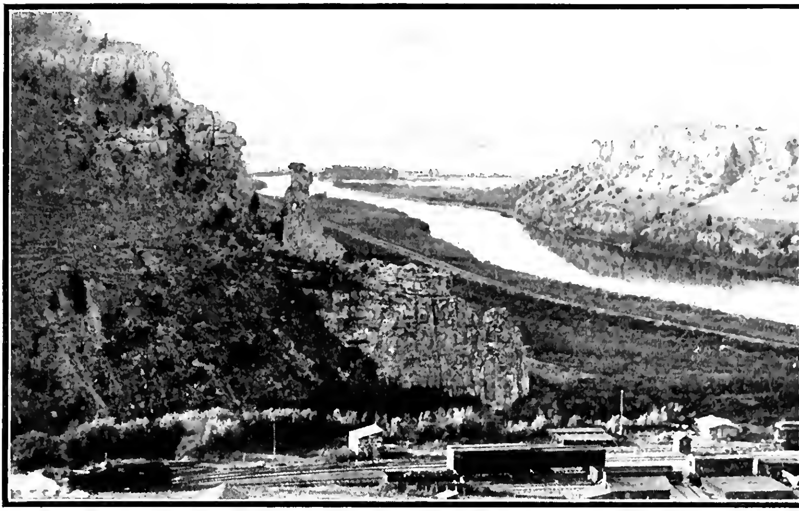


FIG. 33. Notice how the harder rock has resisted the agents of erosion.

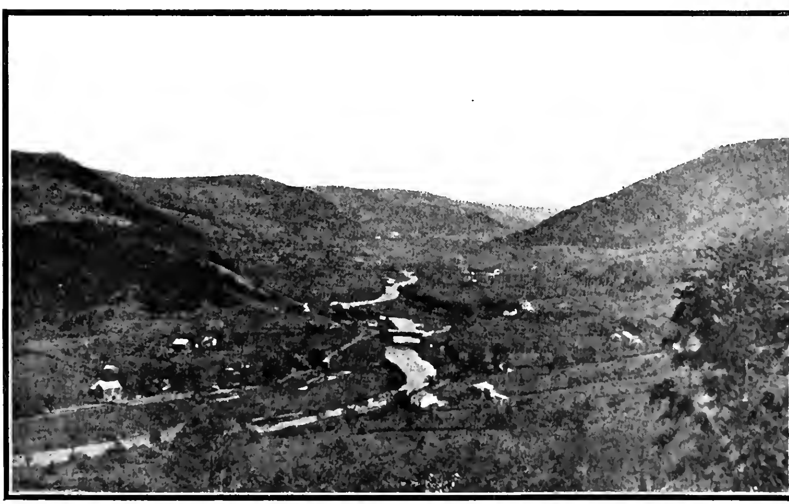


FIG. 34. A river in a mature valley. Note the old, worn-down mountains.

called **water gaps,** and are of importance because all roads and canals in the valley must pass through them.

A young river, again, following an irregular course in the mountains produces **rapids, waterfalls,** and **cascades.** Sometimes it runs into a barrier and cannot pass. Then it forms a **lake** or **pond** and flows steadily until it raises its level high enough to find an outlet. The force of waterfalls is of great value to man in supplying power to mills, dynamos, and other machines; while lakes are much used as lines of travel and commerce. When large lakes have been drained

Fig. 35. The Labrador peneplain.

or have dried up, the bottom forms a very fertile plain because it has for years received the fine sediment from the waters. The great wheat fields in the northern part of the Great Central plain are in the basin of an enormous lake long since dried up.

Mature Valleys. — As a river cuts wider and wider into its valley, carrying off soil now from one side, now from the other, and as weathering acts on the soil and rock, a young valley becomes **mature.** These valleys slope gently, bear fertile soil, and become thickly populated. Highways and railroads are run through and great farms are cultivated. The Connecticut river drains a broad, mature valley of this kind. The river's work is done when it has cut down to sea level; it becomes feebler and instead of carrying its

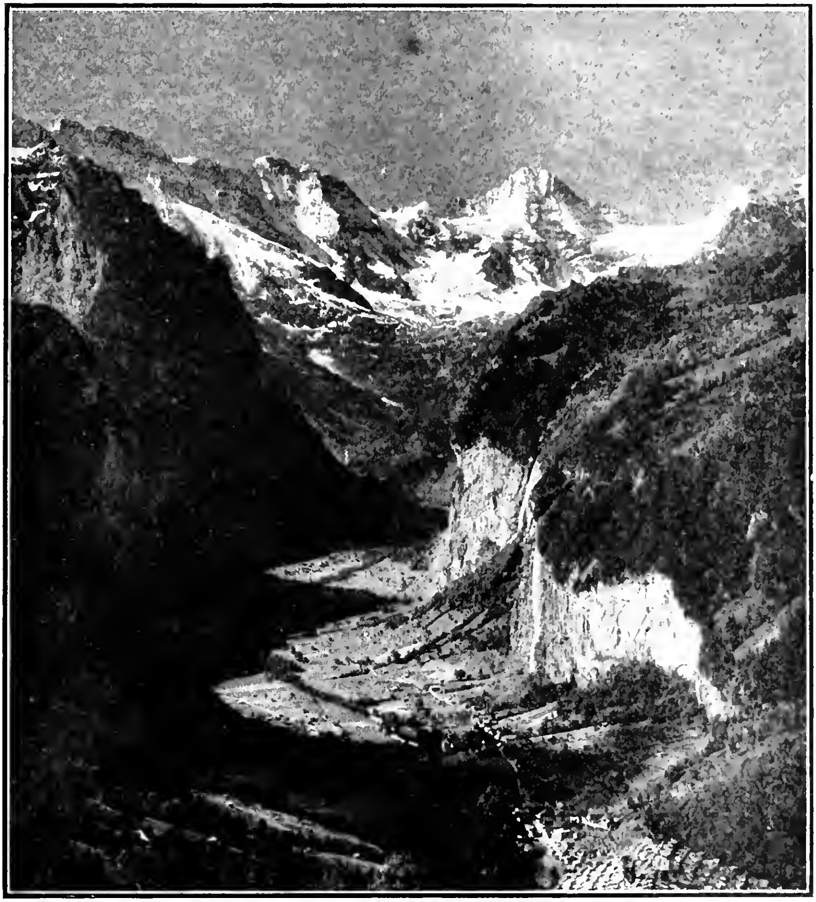


FIG. 36. A Swiss valley dug out by a great glacier.

detritus to the ocean, it now deposits this in its own valley. The flat plains it builds are called **alluvial plains,** and, if flooded at times of high water, as in the Nile valley, **flood plains.** They are good farming regions on account of their fine soil, level surface, and nearness to water.

Old Rivers and Valleys. — A river and valley become **old** when the slopes have been reduced through weathering and erosion

until the region becomes very flat with just enough incline to make the river run. An old land surface, reduced to a low, rolling surface is called a **peneplain** (almost plain). Old rivers always build alluvial plains in their lower portions, like our Mississippi, and the Ganges in India, because they have not enough current to carry out the large amount of detritus brought down by their tributaries.

Fig. 37. The delta of the Mississippi.

Deltas and Drowned Valleys. — When a river empties into the ocean or any body of quiet water, its current is suddenly checked, and it drops the detritus it carries. This builds up in the form of the Greek letter Δ (**delta**). Sometimes, as in the case of the Mississippi, the Nile, and the Orinoco, the main stream divides at the head of the delta and flows across it in several branches. The delta soil makes excellent farm land. A large percentage of the human race is now living on deltas and alluvial plains, especially in China, Holland, and India.

Fig. 38. Estuaries formed by the drowning of valleys.

Where the land is settling, instead of rivers building deltas out in the ocean, the salt water flows into the river basins so as to submerge the valleys or **drown** them. Where this happens to an old or mature valley, broad irregular arms of the sea, called **estuaries**, are formed. San Francisco bay, the Hudson river, Delaware bay are estuaries which are of great commercial importance. When this happens to a young valley, it is narrow and deep, and we have steep walled **fiords**, as in Norway, Alaska, and Southern Chile.

QUESTIONS. — (1) Describe the work of a river from youth to old age. (2) Define river basin, flood plain, tributary, and detritus. (3) How does a young valley differ from a mature valley? Explain the effects upon it of winds, water, and weathering. In which valley are men most likely to settle? Why? (4) How was the Delaware water gap formed? Why should river, wagon roads, and railroads pass through it? (5) What various uses does man make of rivers? (6) How is a lake formed by a river? What uses are made of lakes in North America? In Europe? (7) What is a divide? From the physical maps, tell where you would expect to find divides on the continents. Make a list of the great river systems on the continents. (8) What use does man make of deltas? Locate five great deltas. (9) How are estuaries and fiords formed? What is their importance?

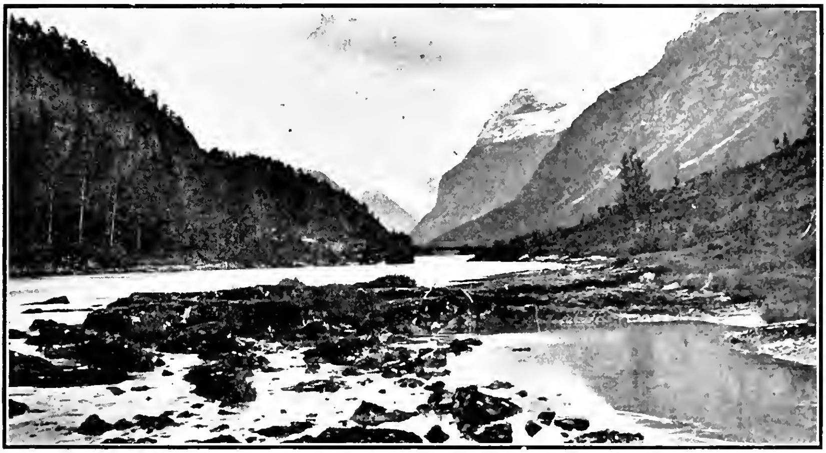


FIG. 39. A Norwegian fiord formed by the drowning of a valley.

Plains. — As the earth's crust raises the land, the level continental shelves are lifted from the water to form sloping **coastal plains.** The plain extending from New Jersey to Mexico along the North America coast was built in this way. These plains are generally sandy and poorly adapted to agriculture except in the higher tracts. **Interior plains** are sometimes formed, as in Eurasia, of detritus washed into a sea-bottom which has been destroyed by the lifting of the crust.

Tundras, found in Siberia and Greenland, are barren plains in winter, and in summer, thawing only at the surface, vast swamps. **Steppes** are open, grass-covered plains generally too arid for farming. The Great Plains of North America were originally a sea-bottom also. Here few elevations rise above the prevailing level of the

country, the slopes are gentle, and they are either arid and treeless or moist and adapted to agriculture. **Prairies** are large areas of plain, treeless when discovered, a condition due to the fires set by Indians

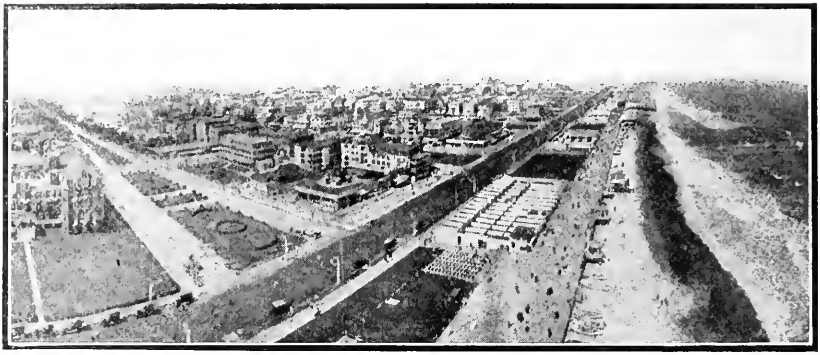


Fig. 40. The broad coastal plain of New Jersey.

in buffalo hunts, or to the fact that the soil favored prairie grass more than tree-growth. Plains similar to these described above are found in each of the continents under various names.

Fig. 41. A view of the Siberian tundra.

Plateaus. — When the earth's crust is raised up in mountains, the plains of the country on either side are also raised so that they become plateaus or elevated plains. Along the base of the Appa-

lachians, the plateau is 2,000 feet above the sea; north of the Himalayas the plateau height is 10,000 feet. Plateaus, like rivers and plains, have life histories. Young rivers cut them into rugged forms with divides, and produce deep valleys with falls and rapids. As they mature, the valleys grow broader through weathering and erosion, the surface lowers, and finally in old age the land is level again.

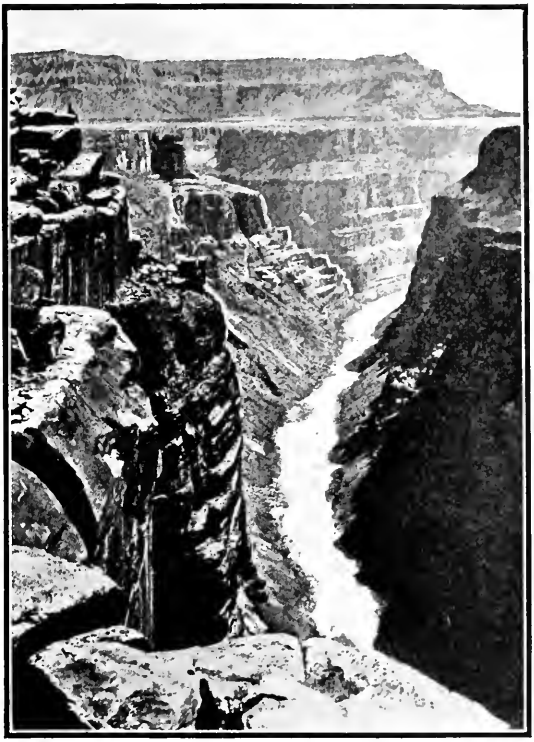


Fig. 42. The Colorado canyon.

A **canyon** is the deep, steep-sided valley of a young plateau river. The Colorado river flows in one for 200 miles, and though it has cut down 6,000 feet, the stream is still young. Of course, a river may have been working for 8,000 or even 80,000 years and yet have a young valley. A river's life work cannot be measured by years but only by the form of its valley or canyon.

Plateaus are often cold and arid, and some are true deserts, though in moist countries they are forest-covered. They are usually sparsely settled, and cattle-raising on arid plateaus is the leading occupation, while lumbering is followed on some moist plateaus. In some cases plateaus have been entirely worn away and only a few flat-topped table mountains remain, with vertical sides. These are called **mesas** (tables) and **buttes.**

Deserts. — These are regions in which few forms of life can find

an existence. Antarctica by reason of its ice and cold is a desert. The name desert, however, is usually applied to those regions where the rainfall is so scanty that only especially adapted animals and plants can live in them. Some rain falls in the driest of deserts even though, as in Peru, dry periods of seven years may be known. Most deserts are plains and plateaus with much sand, though in Utah and in the Sahara mountain ranges are found. Winds move the sand about in severe sand storms, and form belts of sand dunes which have been known to cover cities. Except on the **oases,** which are either scattered springs or else places where streams descend from mountains which are high enough to get moisture, deserts are unfavorable to settlement by man.

The Life History of a Mountain. — We have seen how, as the heated interior of the earth cools and shrinks, the crust settles down. Since it is now too large to fit the centersphere, it wrinkles and the layers of rock bend upward to form a mountain system. As the layers or strata slowly bend, the strain becomes too great and the rocksphere splits and one part slips upon another, or they support each other in a great ridge. This jars the earth, producing earthquake shocks; while through the deep fissures thus formed, lava may rise forming volcanic cones.

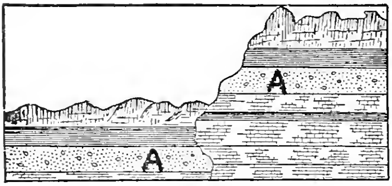


FIG. 43. Strata broken by great pressure.

As soon as the land rises, the agents of weathering and erosion, winds, air, rain and rivers, heat and cold, plants and animals, attack it; and the higher the mountain rises, the fiercer they become in their efforts to wear it down. Valleys are formed between the ridges, streams cut gorges across them, the hard rock remains as ridges and peaks, while the soft rocks are cut away, forming valleys and passes. Mountains in this stage, like the Alps, the Andes, the Rockies, and the Himalayas are called **young mountains.** The folding of the strata and the later erosion of the land are of great importance to man, for through these means the valuable mineral deposits of mountains are brought to light and mining is made possible (*Figure 44*).

Finally the uplifting of the rocksphere ceases, but the forces are still busy broadening the valleys and lowering the peaks. The mountains become smooth, forested, and sloping, and, like the Appalachians and the mountains of Norway and Scotland, are now called **mature.** In the end, after countless centuries, they become old and are reduced to a series of rolling hills or even level surfaces. New York City and Philadelphia are situated on such old worn-down mountains. Sometimes, however, another uplift will come and give new life to an old mountain region. When this happens, its life history is repeated.

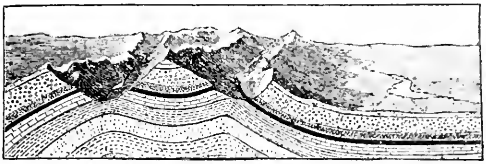


FIG. 44. Strata bent upward and broken. Note the layer of coal.

FIG. 45. Notice the timber line and the snow line on these Swiss mountains.

The Climate of Mountains. — The higher a mountain rises, the colder it becomes. Some have perpetual snow on their summits, and glaciers in their valleys. The line marking this belt of snow is called

the **snow line,** and the line above which trees cannot survive is called the **timber line.** Day and night bring great changes in temperature, and we have learned how frost action splits off layers of rock. The strong winds, the heavy rains, blow or wash these fragments down; and the melting snows above the timber line, where there is no vegetation to hold the soil and rock together, form streams to carry the detritus away.

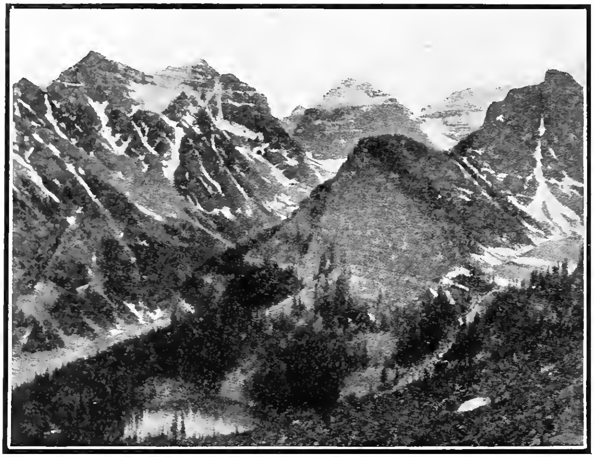


FIG. 46. A young mountain range in the Canadian Rockies.

Owing to the climate and soil conditions, mountains are sparsely settled. Agriculture may flourish at the base, but the area available for cultivation becomes smaller the higher one goes. Grain fields are found higher up, and grazing areas that support herds for a month or so in summer are common above the timber line. Above this, however, plant and animal life is very sparse.

Relations of Mountains to Man. — Mountains have always been barriers, hemming in people and animals in one region and checking their passage by ruggedness and coldness. The Appalachians, Alps, Pyrenees, and Himalayas have all been effective barriers and boundaries, conquered by man only with difficulty. The important parts of a mountain system, then, are the lowest points in the ranges where man can cross most easily.

On the other hand, mountains afford beautiful scenery and are inspiring. They are summer resorts for health and pleasure, and are important as timber reserves; while many ranges are Nature's great storehouses of gold, silver, lead, copper, iron, coal, and building stones.

QUESTIONS. — (1) Explain the work of the crust in mountain building. (2) Tell the life history of a mountain. (3) Make a list of the great mountain ranges on the continents. (4) From the physical maps, tell where you would expect to find the great plains of the world. The great plateaus. (5) Explain the difference between coastal and interior plains. (6) Describe possible effects of avalanches and landslides. (7) What forces are active in attacking mountains? (8) Explain why man should be interested in prairies, oases, peneplains, canyons, steppes, mesas, and tundras. (9) What do snow lines and timber lines indicate to man? (10) Explain the effects of mountains on communication and commerce in Europe, Asia, and South America. On the history of nations in these continents. (11) Tell about their effects on the characteristics of mountaineers in the Alps, in Scotland, Kentucky, and the Pyrenees.

CHAPTER IV

THE MOTIONS OF THE EARTH AND THEIR EFFECTS

Rotation. — The rotation of the earth occasions what we call sunrise and sunset. For many years people believed that the sun moved across the heavens every day and that the earth was stationary. We can understand their error when we recall that as we ride in a rapidly moving car trees, fences, and houses often appear to be moving in a direction opposite to that in which we are traveling. It seems as though we are stationary. In just this way, the rotation of the earth causes the sun and the stars to appear to move, to rise and to set, while in reality we are riding by them. Since the sun rises for us in the east, it is plain that the earth is turning eastward: that is, from west to east. One complete rotation is made in about every twenty-four hours; and since the earth is an opaque sphere, only one half of its surface can be lighted at one time. The boundary line between the light and dark parts forms a great circle called the **Circle of Illumination.**

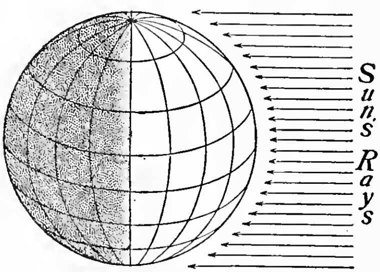


FIG. 47. The circle of illumination passing around the earth.

Effects of Rotation. — The spinning motion of the earth on its axis leads to the following results: (1) The movement produces the alternation of day and night. (2) It leads to the knowledge of the earth's axis, equator, and poles. (3) It produces the flattening at the poles. (4) It causes the apparent movement of the skies in the opposite direction.

Revolution. — While the planet spins once around on its axis in one day, $365\frac{1}{4}$ of those daily rotations take place while the earth

is making its year-long journey about the sun. In doing this, it travels through an enormous orbit of 585,000,000 miles, so that every month we are able to view different constellations or groups of stars. We have already learned that the axis of the earth is not straight up and down like a lead pencil held perpendicular to your

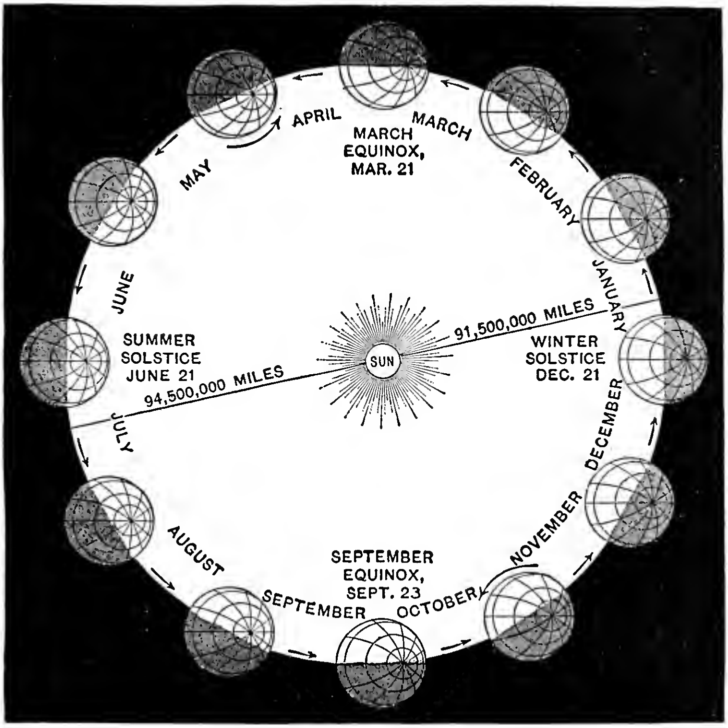


FIG. 48. Position of the earth in its orbit each month.

desk but is inclined $23\frac{1}{2}°$ from the perpendicular to the plane of the earth's orbit, as in *Figure 50*. The end of the axis, the north pole, remains in one position pointing always to the Pole star.

In *Figure 48* we can see the earth circling about the sun at the different months in the year. Notice the movement of the north pole from September 23 away from the sun until December 21, and then its gradual return toward the sun until the position of March

21 is reached. Now it swings toward the sun until the position of June 21, and then away, until September 23 is reached once more and the year is ended. In this long trip, the axis has always remained **parallel** to its first position.

Day and Night over the Earth: Equinoxes: Circles. — In *Figure 49,* which shows the earth on March 21, although the axis is inclined, neither pole is turned from the sun. The circle of illumination, therefore, extends from pole to pole. At the equator the sun's rays are vertical, and day and night each lasts for twelve hours all over the earth, since it will turn completely in twenty-four hours. This time is called the **spring** or **vernal equinox** (equal days and nights).

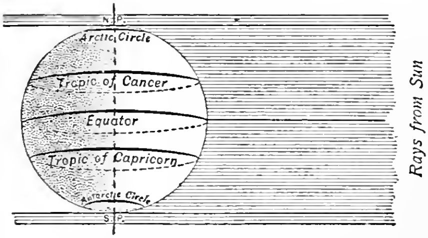


Fig. 49. The position of the earth at the equinoxes.

Next, in *Figure 50* the earth has moved to the position of June 21. The sun's rays, since the axis is tilted toward them $23\frac{1}{2}°$ from the perpendicular, reach the same number of degrees beyond the north pole and give us the location of one of the great circles of the earth — the Arctic circle. While the earth was in the position of March 21, the sun's rays were vertical at the equator, but during April, May, and June they have crept northward on the earth and are now vertical at a point $23\frac{1}{2}°$ north of the equator. This gives us the location of the tropic of Cancer, which is on the line on which the sun seems to turn.

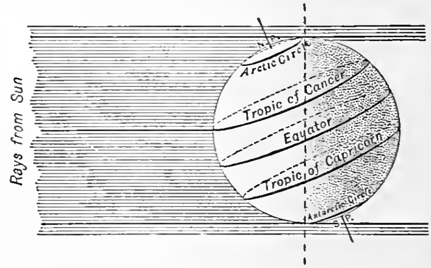


Fig. 50. The position of the earth at the summer solstice.

During this period from March 21 to June 21, day is continuing week after week, at the north pole. The Eskimos have their long stretch of unbroken daylight. The midnight sun in the Arctic circle appears also at midday, and circles around the heavens near the horizon. It reaches its

highest point on June 21. At the south pole, just the opposite conditions prevail, the area about the pole being shrouded in weeks of darkness.

At that part of the earth's surface near the equator, the sun reappears every morning; by noon it mounts directly overhead, and then seems to set. At this region, the days and nights are always of equal length (twelve hours); at all other places they are unequal, except when the earth is at the equinoxes in March and in September.

On September 23 we find the pole has swung away from the sun, the rays are again vertical at the equator, days and nights are equal over the earth. Here we have the **autumnal equinox.**

Figure 51 shows us the earth three months later when the pole has swung farther away from the sun. We get the location of the Antarctic circle, 23½° beyond the south pole, by the extent of the sun's rays. The tropic of Capricorn is located 23½° below the equator because the sun's rays are then vertical on that great circle. The word tropic means "turning-point," since the sun, when at either of the two tropics, seems to turn and start back — either northward or southward, as the case may be. The south pole, at this time, is enjoying unbroken day and knows no night, while the Arctic regions are in darkness; and we in the northern hemisphere are having shortest day and longest night.

The Solstices. — At December 21, the sun in our northern hemisphere is at its lowest position in the heavens, and short days, long nights, and winter prevail. Since the sun seems to stop at this low point for a few days before it begins to rise, we call its position the **winter solstice,** or "standing-still" of the sun. On June 21, it reaches its highest point in the sky for us and begins to return to the autumnal equinox. June 21 then is called the **summer solstice,** the sun appears north of the equator, and long days and summer prevail in the northern hemisphere.

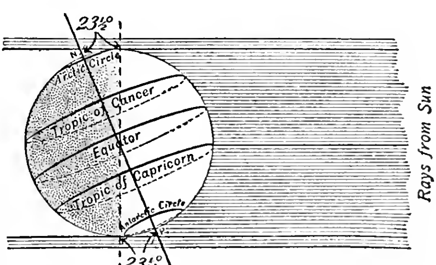


FIG. 51. The position of the earth at the winter solstice.

Variation in the Length of Day and Night. — We can see that the change in length of day and night is due to the inclination of the earth's axis to the plane of its orbit. From *Figure 50* notice that when the sun is north of the equator, more than half of the tropic of Cancer and therefore of every line parallel to it, in the northern hemisphere except the equator, is in the sunlight at a time. At this time, then, we are about fifteen hours in passing through our period of day, and nine hours in rotating through our period of darkness. Days, then, are long and nights short in the northern hemisphere. The length of the day increases as one goes northward.

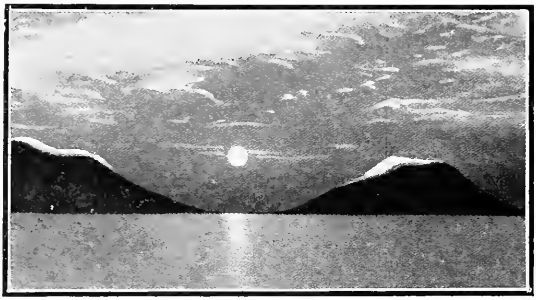


FIG. 52. The midnight sun at North Cape, Norway.

In London, around June 21, days are $16\frac{1}{2}$ hours long; at Stockholm, they are about 19 hours; in the north of Norway, the sun does not set at all during the greater part of May, June, and July. And thus we have here the Land of the Midnight Sun. Likewise *Figure 51* shows that when the sun is south of the equator, its rays being vertical at the tropic of Capricorn, less than half of the tropic of Cancer and of all lines parallel to it north of the equator are in the sunlight at one time. So that now the days are short, about nine hours in length, and nights are fifteen hours long in the northern hemisphere, while in the southern hemisphere nights are short and days long. In London the December days are only $7\frac{3}{4}$ hours long, and in the middle of the day the height of the sun above the horizon is only 15° instead of 62° as in June.

The Seasons: (1) Inclination of the Earth's Axis. — The different positions of the earth in its trip around the sun have a great effect on the way in which man lives on this planet. We have seen that not only our light but also our heat comes from the sun, and we can understand now that this heat is spread during each year over different parts of the planet's face. Think of the changes the seasons require in our clothing, our food, our games, our modes of travel,

and recreations. Think of the effect of the changes on crops, trees, furs of animals, and migration of birds. If the earth remained in the position of the vernal or spring equinox, the rays would extend from pole to pole. As the planet rotated, all places would have days and nights of equal length, and throughout the year the distribution of heat would be the same. We could have no change of seasons.

If the earth remained in the position it has at the summer solstice of June 21, since the axis would be inclined $23\frac{1}{2}°$, the north pole would always be tipped toward the sun to get its light and heat. The Eskimos in the Arctic circle would have daylight forever, and their bitter cold climate would moderate. The south pole would be in perpetual twilight, and the sun's heat would be felt very little. As heat as well as light comes from the sun, it would always be summer in the northern hemisphere and winter in the southern. If the axis were inclined so that the south pole were tipped toward the sun as on December 21, the opposite condition would prevail in each hemisphere. There would be perpetual night at the north pole and constant winter for us. Perpetual summer would prevail in the southern hemisphere and constant daylight at the south pole.

From *Figure 20* we know that the earth's axis always is inclined, but owing to another cause of the seasons, we do not have perpetual winter or summer in our northern hemisphere.

The Seasons: (2) Earth's Revolution. — Since the axis is always inclined $23\frac{1}{2}°$, it is the earth's revolution that causes first the north pole to be turned to the sun and then the south pole. During its movement the axis pointing to the Pole star is always nearly parallel to any former position. Unless the axis were constantly parallel to its former positions, the change of seasons would not occur. The revolution and the inclination of the axis, then, cause different portions of the earth's surface to be turned in succession toward the sun, and to this fact we can attribute the change in seasons.

The Seasons: (3) Slant of the Sun's Rays. — Our seasons are likewise due to the slant at which the sun's rays strike the earth at different times of the year. In *Figure 53*, A D is a surface on which eleven rays coming from the sun fall at right angles. All eleven rays give light and heat to this surface. But if surface A D is shifted into

the position A C, so that the light strikes it at an angle, only six of these rays strike it. The amount of heat or light received by A C is therefore only $\frac{6}{11}$ of the amount received in position A D. *Figure 54* shows this principle applied to the earth. Eleven rays strike E F perpendicularly and give heat to this surface. The same number of rays are spread over the wider surface G H, however, when they strike the earth at a slant. The surface G H, of course, receives less benefit when the same amount of heat must warm a larger area. When they strike the surface perpendicularly, then, the sun's rays are more concentrated and intense, and have a greater heating effect on the earth.

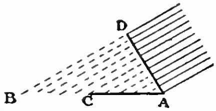


FIG. 53.

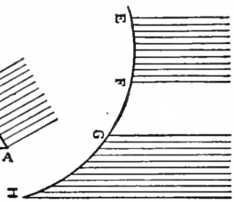


FIG. 54.

We can see the effect of the slant of the rays on our earth by referring to *Figure 55.* On December 21, the midday sun is low in the heavens in our region, and its rays reach us at the greatest slant. That is the beginning of our coldest season. As the rays become more nearly vertical, spring comes, until on June 21 the midday sun is high in the heavens, the rays are then most nearly vertical, and we receive the greatest quantity of their heat. As the autumnal equinox approaches, they slant again and the earth cools. So that it is the revolution of the earth, together with the inclination of the axis, that causes our seasons by continually changing the slant at which the sun's rays fall upon us.

The Zones: Light Belts. — We learned from *Figure 51* that on December 21, when the north pole is farthest within the shadow, the sun's rays are vertical as far south as the tropic of Capricorn. On June 21, when the north pole is farthest within the light, the sun's rays are vertical as far north as the tropic of Cancer. That belt around the earth between these circles within which the rays are always vertical somewhere is called the **torrid zone** (girdle or belt) or **tropical light belt.** We found the Arctic circle to be the line which was reached by the sun's rays at the summer solstice in the northern hemisphere and the Antarctic circle to mark their limit during the summer season of the southern hemisphere. In these belts the rays strike the earth at so great a slant that little effect is made upon the

earth. These circles mark for us the **north frigid zone** and **south frigid zone.** The northern belt lies entirely in darkness on December 21, while the southern belt has sunlight at this time. On June 21, the northern belt is bright while the south frigid zone is having perpetual night.

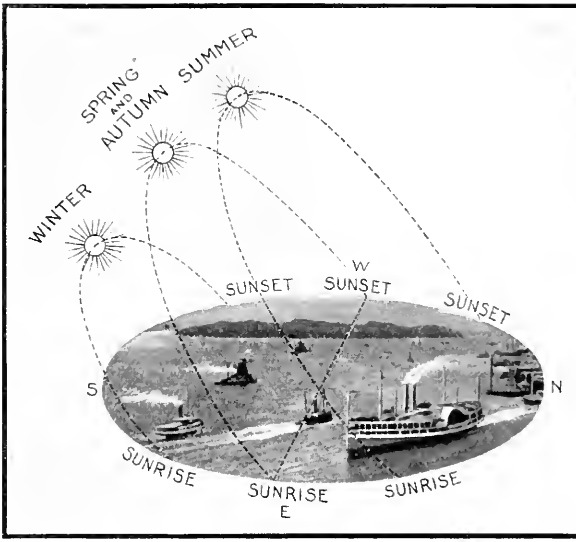


FIG. 55. The daily course of the sun at the time of the solstices and the equinoxes.

Between the torrid and frigid zones are two belts where the sun's rays shine every day but are never vertical. They strike the earth, however, at less of a slant than in the cold belts. These are the **temperate zones.** *Figure 56* shows the zones marked out on the earth's surface according to the great circles. But it would be quite incorrect to say that there is any sharp boundary between any two of them. Many other causes affect climate so that we can find a very hot climate in the temperate zones and never-melting snow in the torrid zone. The real boundaries are shown by the irregular lines in *Figure 131*.

Seasons in the Zones. — We must be careful not to imagine that the seasons are the same all over the earth. In our north temperate zone and in the south temperate, there are the four seasons, spring, summer, autumn, winter. In the north and south frigid zones, days vary in length from four hours at the time of the equinoxes to six months, and only two seasons are known, summer and winter. In the torrid zone, where days and nights are equal, winter is unknown; and there are two seasons, the dry and the rainy. In the

southern hemisphere, the seasons are always the opposite of those in the northern hemisphere. In this way, north of the equator the dry season extends from October till April and the rainy season extends from April until October. In the belt just south of the equator, these seasons are reversed.

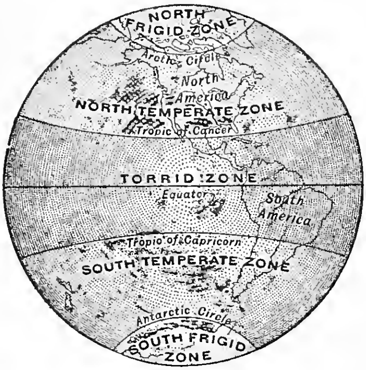


FIG. 56.

Although the most direct rays of the sun fall at noon, the warmest part of the day is usually two or three hours later. So, although the hottest rays fall at the summer solstice, yet June 21 is not the hottest part of the season. Our warmest weather does not come until some time afterwards. The earth continues at this time of the year to receive more heat during the day than it gives up during the night. Thus the great heat of a July or August day is not produced entirely by the sun of that day, but is an accumulation of the heat of the several preceding weeks. For the same reason December 21 is not our time of greatest winter cold. The earth continues to lose more heat during the night than it receives during the day, and the greatest cold does not obtain until some time in January.

Summary of the Seasons. — Refer to the diagrams and answer each question, for (1) The spring equinox, March 21. (2) The summer solstice, June 21. (3) The autumnal equinox, September 23. (4) The winter solstice, December 21.

(1) How do the poles lean with reference to the sun?

(2) Where do the northernmost and southernmost rays of the sun fall?

(3) On what circle of the earth are they vertical?

(4) What is the length of day and night? Where are they longest? Where shortest?

(5) What season is it in the northern hemisphere? In the southern? In the five zones?

QUESTIONS. — (1) Suppose the earth rotated on its axis but did not revolve around the sun, would we have day and night? (2) Tell what the result would be if the

earth had no motion of rotation on its axis but merely revolved about the sun. (3) If the earth's axis were perpendicular to the plane of its orbit, how would the length of day and night be affected? (4) Tell about the seasons of the earth in this case. (5) Why did people once believe the heavens moved and that the earth was stationary? (6) State the cause of the zones. (7) Tell the simple meaning of *zone, solstice, equinox, equator.* (8) What are the effects of the earth's revolution? (9) Tell in what way the change of the seasons affects your games and exercise. (10) How do the seasonal changes affect a farmer's life? A bricklayer's work? A storekeeper's business? A steamship captain's duties? (11) At what time does your shadow always point directly north? (12) At noon on December 21 how would a man's shadow be cast if he stood at the equator, Cancer, Arctic circle? (13) On June 21 at these points? (14) What would be the effect if the earth's axis were always in the position shown in *Figure 49*? In *Figure 50*? In *Figure 51*? (15) If the earth revolves at such great speed why do we not notice it? (16) What changes do the Eskimos notice in the sun's position every year? (17) Give two causes of our change of seasons. (18) Why are the sun's rays more intense when it is high in the heavens than when it is lower? (19) Are the sun's rays ever vertical at New York? (20) On what day does the sun appear farthest north? (21) From *Figure 62* find how many miles we are from the tropic of Cancer. (22) Which way does the sun seem to be moving on June 25? Why? (23) Make a list of all the large countries in the north temperate zone. The south temperate zone. (24) What season are people having now in the south temperate zone? (25) Should you expect to find a very great change in temperature in crossing the tropic of Cancer? (26) Suppose the earth rotated once every ten hours. What effect would you note? (27) Suppose a rotation required fifty hours; tell all the effects you can think of.

EXERCISES. — (1) Draw a two-inch circle and show day and night as it would be on March 21. (2) Write a paragraph explaining why we have four seasons. (3) Place in your notebook your observations on the length of the days for one week. Are they growing longer or shorter? (4) Make a table under your observations showing in which months they grow longer and in which shorter. (5) Keep for a week a record of the length of your shadow when you stand on the same spot at 8:30, 12:30, and 5 o'clock. Explain the changes. (6) Make a diagram to show the earth inclined to its orbit 45°. (7) Make a diagram showing four positions of the earth when the axis is perpendicular to the orbit. (8) Where would the tropics be if the axis were inclined 45°? Where would the polar circles be? (9) How would the heat and cold compare with what we now feel? (10) What other effects can you think of? (11) Make a diagram of the earth with its axis parallel to the plane of its orbit. What effects might be observed should this change take place? (12) How much should the axis be inclined to bring the tropic of Cancer to New York? (13) How much should it be inclined to bring the Arctic circle to New York? (14) Why is the heating effect of the vertical rays of the sun greater than that of the slanting rays?

CHAPTER V

LATITUDE; LONGITUDE; TIME

Directions on the Earth. — From the fact that the earth rotates on its axis, men have been able to determine for us certain directions on its surface. We know that it turns toward the **east** or the "dawn-point" and that the opposite direction is the **west.** We know that the Pole star remains fairly constant over the north pole of the earth and that the opposite direction is the south. If we stand with extended arms facing east, our arms will be parallel with the earth's axis. Our left arm will point **north,** our right arm, **south.**

It is rather easy to locate a house in a city like New York. We know that one avenue, Fifth, has been selected to divide the Borough of Manhattan into an east and a west side. So that if a man says he lives on Third avenue, we know at once on what side from Fifth avenue he lives, and that to reach his house we should have to walk four blocks east from the dividing avenue. But we should also need to know on what part of Third avenue his house is to be found. We see that in order to determine this question the city has been divided also by streets which run east and west. Thus if this man lived on the corner of Third avenue and East 32nd street, we should know not only that his house was east of a certain dividing line but also north of a certain other line. We should then ride up thirty-one blocks from 1st street to see him.

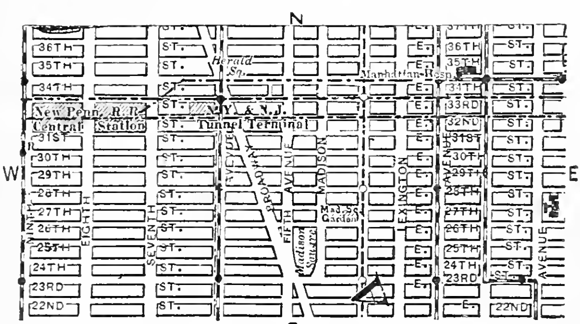


FIG. 57. Map of a part of a city.

Latitude. — We might compare the earth to a great city. The equator, like a middle street, divides it into a north and a south part, while many circles running east and west like streets divide the hemispheres into smaller sections. These circles running parallel to the equator are called **parallels of latitude.**

In a circle there are 360 equal divisions called **degrees.** In the circumference of the earth passing through the poles and in the equa-

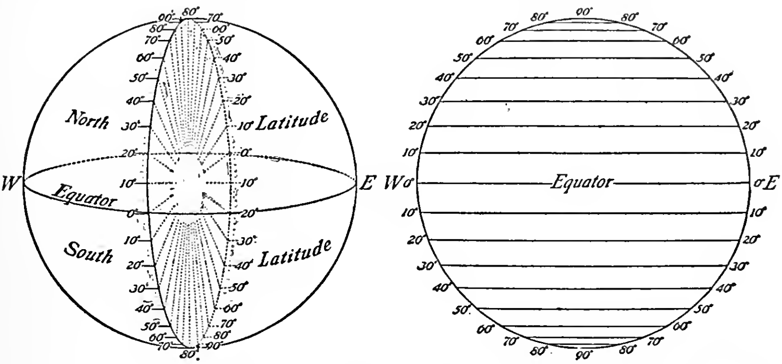
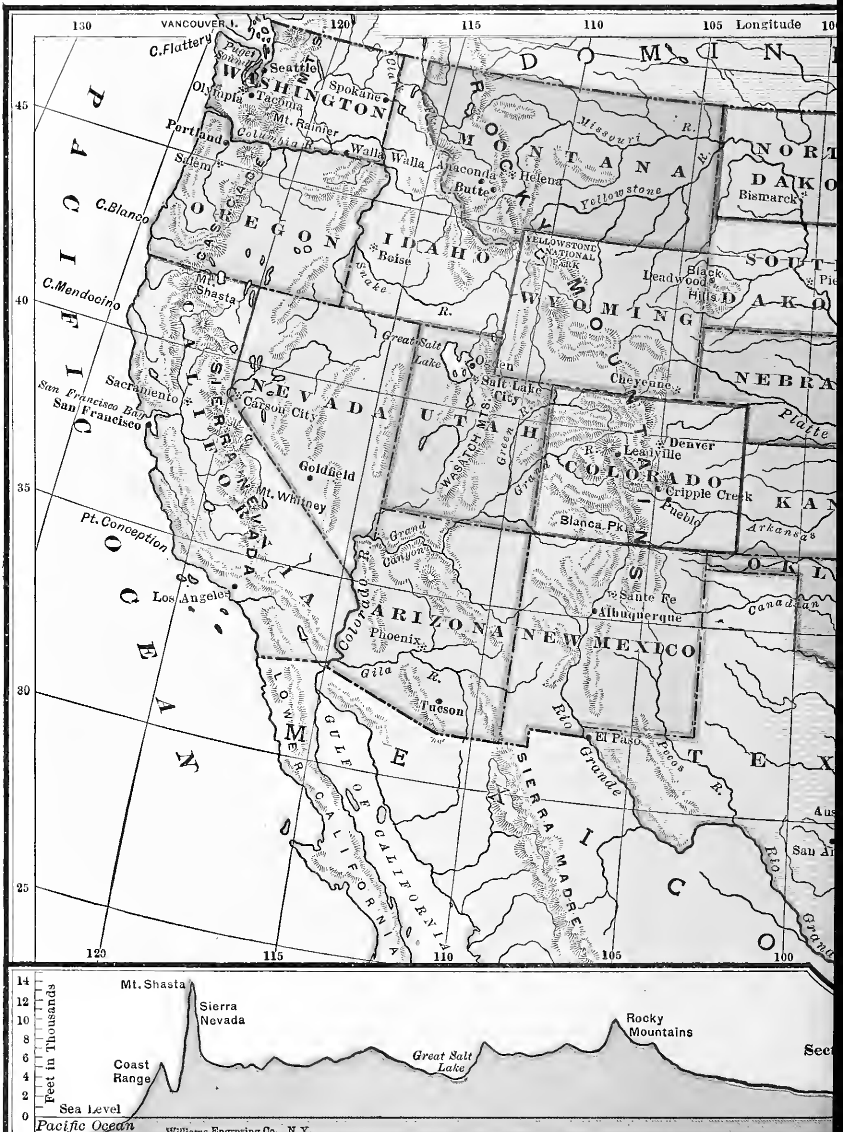


FIG. 58. Degrees of latitude and parallels by means of which points are located on the earth as north or south of the equator.

tor also there are then 360°. Since the equator divides the earth into two hemispheres, there are 180° in each hemisphere. Between the equator and the poles there are 90°. The distance north or south from the equator, measured in these degrees is **latitude.** Each of these 90 degrees of latitude measured on the earth's surface, would be about 69 miles in length. San Francisco is near the 38th degree of north latitude, while Rio de Janeiro is 23° south latitude.

The latitude of a place is most easily found by locating the position of the Pole star. The North star appears in the northern horizon to a person standing on the equator and the Southern Cross is seen nearly on the southern horizon. To an explorer at the pole the North star appears directly overhead. At every point between there would be a different angle between the plane of the horizon and the line from the observer's eye to the North star. In the northern hemisphere the latitude may be found by measuring this angle between the Pole star and the horizon.



EXERCISES. — (1) Give the extent of the United States in degrees of latitu
In degrees of longitude. (2) Name the states whose boundaries are fixed by parallels
meridians. (3) Give the approximate latitude of St. Louis, San Francisco, Mob
Helena, and Duluth. (4) Name the states through which the 40th parallel of no
latitude passes. (5) The 85th meridian of west longitude. (6) Give approximate la
tude and longitude of St. Paul, New York, Boston, Kansas City, and Seattle. (7)

ottle drifts from 27° north latitude, 92° west longitude to 34° north latitude, 73° west ngitude. Trace its course on the map. (8) Locate in latitude and longitude Quebec, Vinnipeg, Los Angeles, and Austin. (9) A vessel passes from 47° north latitude, 92° est longitude to 29° north latitude, 94° 30′ west longitude. Name the waters through hich it steams. (10) A derelict drifts from 46° north latitude, 129° west longitude to 30° orth latitude, 116° west longitude. Trace its course and determine its present position.

Since parallels are at equal distances apart all over the world, we can use latitude to measure distance. We can say, for example, knowing the latitude of San Francisco and Rio de Janeiro and also the fact that a degree of latitude is the equivalent of sixty-nine miles, that the Brazilian capital is 945 miles nearer the equator than is San Francisco.

Longitude. — It might be very well to know that a city we are seeking is in latitude 40° north, but since this parallel extends around the earth, the task of locating the place would be hopeless. It would be like telling a person that a man could be found in 32nd street. Some means must be found for locating places east and west on these parallels. Other imaginary lines are used. These great circles which extend around the earth through the poles are called meridian circles, and each of the semicircles, extending from pole to pole, a **meridian,** or midday line.

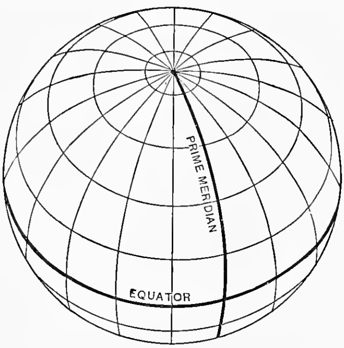


Fig. 60. Great and small circles. Notice that all meridians meet at the poles and that parallels of latitude are smaller and smaller the farther they are from the equator.

Any avenue in New York might have been chosen as well as Fifth avenue to divide the city into an east and a west side. The important point is that everybody accepts the same avenue as the dividing line. The same thing is true of these meridians. In this way the great circle passing through **Greenwich** at London, in England, has come to be accepted as the dividing line on the earth between eastern and western hemispheres. Greenwich was chosen because there was situated there a large observatory, fitted with telescopes and various other instruments by the aid of which the stars and planets were observed and very important facts about our universe discovered. So England thought this a fitting place from which to begin the numbering of the meridians. The Greenwich meridian is called the **prime** or "first" **meridian;** and its opposite meridian, 180° east or west from Greenwich, is called the **sub-meridian.** In the northern hemisphere the sub-meridian passes near Rat island, one of the Aleutian group belonging to the United States;

and in the southern hemisphere it passes near the Fiji islands which belong to Great Britain.

As shown in *Figure 61*, degrees are designated east and west from this prime meridian. Any place, like Buffalo, 79° west longitude,

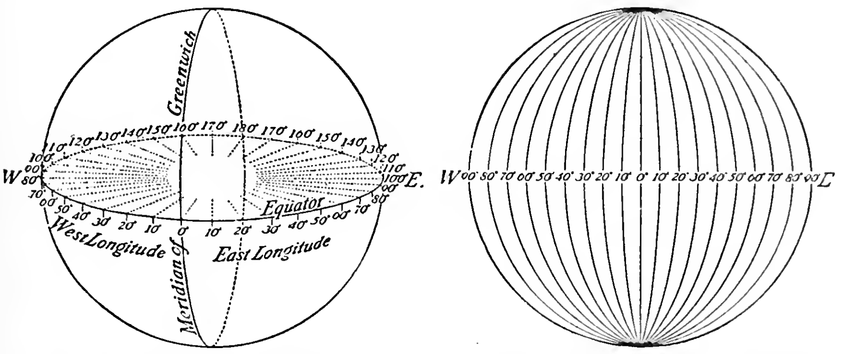
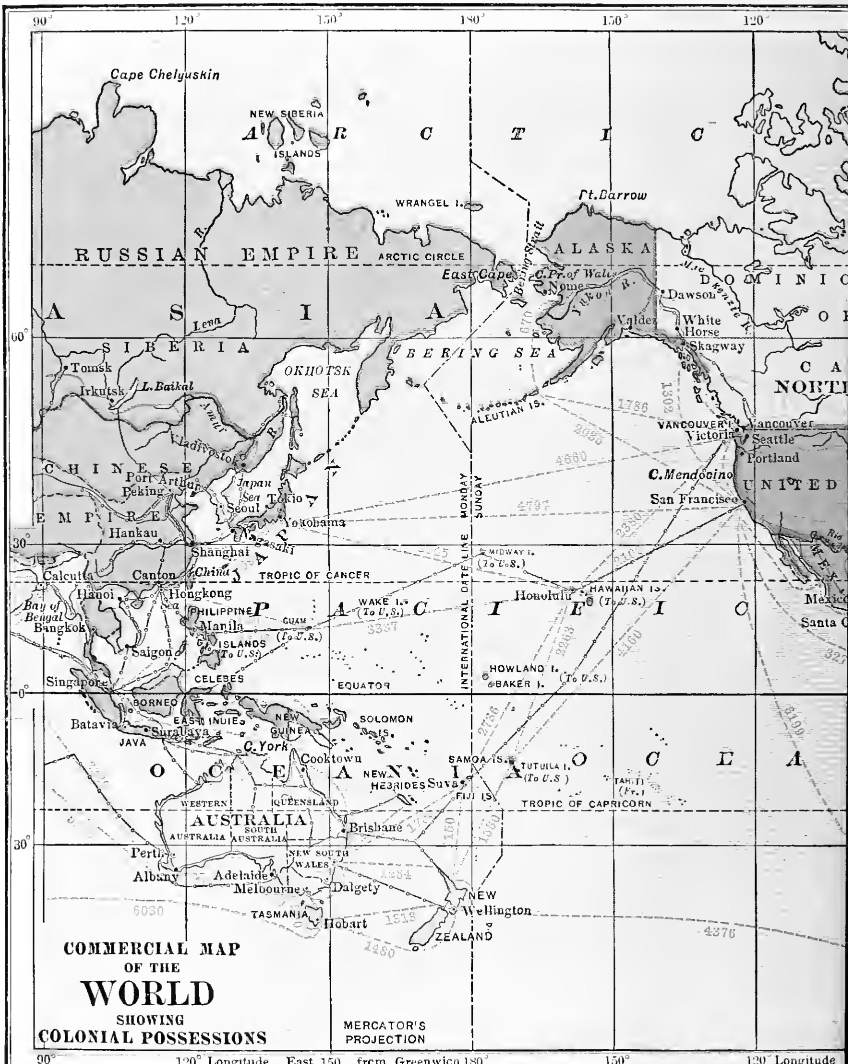


FIG. 61. Degrees of longitude and meridians by means of which points are located as east or west of the prime meridian.

is 79° west of the prime meridian; while Paris, 3° east longitude, is 3° east of the meridian of Greenwich. Longitude is distance east or west from the prime meridian, measured in degrees. The circles that form the meridians are called circles of longitude. Since these are drawn 1° apart there are 360 meridians. You notice in *Figure 61* that they are numbered from 1° up to 180° in both directions from the Greenwich meridian. The prime meridian itself is 0° longitude. At the equator a degree of longitude measures 69 miles. As the meridians approach the poles they draw closer together, so that this measure constantly decreases. At the 20th parallel of latitude a degree of longitude measures about 65 miles, at the 80th parallel, about 12 miles.

QUESTIONS. — (1) How can all places on the earth be located in a north and south direction? (2) In an east and west direction? (3) Why are meridians not parallel to one another? (4) How many degrees of latitude are found between the poles? (5) What is the length of a degree of latitude? (6) Why was the meridian of Greenwich chosen as the prime meridian? (7) Explain why the people of Uruguay are never able to see the Pole star. (8) What uses are made of parallels and meridians? (9) What is meant by sub-meridian?



EXERCISES. — (1) From the map give the approximate latitude and longitude of Rome, Havana, Paris, and Calcutta. (2) Find cities around the earth near the 42nd parallel of north latitude. (3) A derelict drifts from 40° north latitude, 20° west longitude to 5° north latitude, 40° west longitude. Trace its course on the map. (4) Give the approximate latitude and longitude of Cape Town, Bombay, St. Petersburg, and Cairo. (5) What place is located at 25° north latitude and 81° west longitude. (6) Name eight large cities from which the Pole star can be seen. (7) Name all the countries through which the 30th parallel of north latitude passes. (8) The 30th parallel of south latitude. (9) The 60th meridian of west longitude. (10) Find as many places as you can where parallels and meridians are used as boundaries. (11) Find five cities with the same approximate latitude as New York. (12) What islands are situated near 15°

north latitude and 120° east longitude? (13) A bottle drifts from 35° north latitude, 150° east longitude to 45° north latitude and 135° west longitude. Trace its course on the map. (14) Give approximate latitude and longitude of Christiania, Vancouver, Brisbane, and Valparaiso. (15) Give the approximate latitude and longitude limits of Venezuela, Alaska, and Persia. (16) If a vessel sails from 13° north latitude, 80° east longitude to 52° north latitude, 0° longitude, through what waters will it pass? (17) A bark made the run from 35° south latitude, 56° west longitude to 35° south latitude, 140° east longitude, a distance of 10,000 miles in thirty-eight days. Find these two ports and determine her average daily run. (18) Determine the latitude and longitude of Berlin, Hongkong, Naples, Peking, and Buenos Aires.

The Division of a Degree. — On a very large map of the state of New York, the circles of latitude would be too far apart to be of much use. Likewise the circles of longitude. It is customary to divide each degree into sixty equal parts called **minutes.** Each minute is in turn divided into sixty equal parts called **seconds.** In this way a degree of latitude may be measured by 3,600 parts and accordingly a place can be located with more accuracy. The degree sign is °; the minute sign ′; and the second sign ″. Thus the location of the city of New York, 40 degrees, 45 minutes, 23 seconds, is marked 40° 45′ 23″, north latitude. This line passes through the grounds of Columbia University.

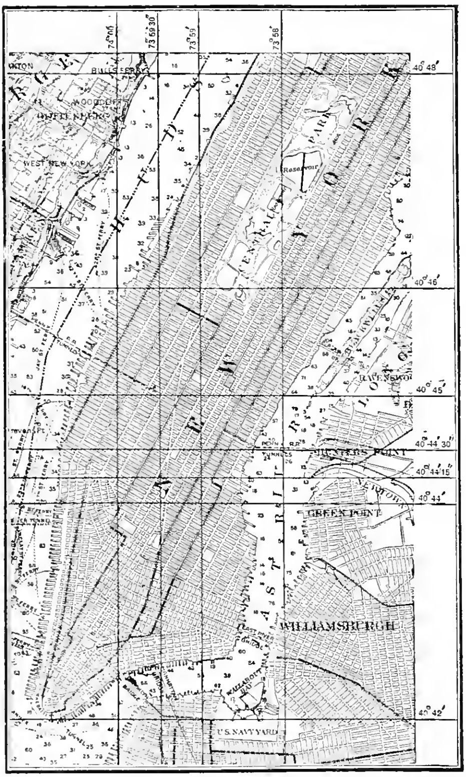


Fig. 63. A map showing minutes and seconds of latitude and longitude.

Importance of Latitude and Longitude. — Latitude and longitude are very important, especially in locating spots in the great plains or on the ocean, where no one would know his position on the earth unless he could calculate it from the stars. Ship commanders find their latitude and longitude daily, plotting the position of their vessel on large charts. Everyone who uses maps makes use of latitude and longitude, because all maps are drawn to show the positions of places in the world by their latitude and longitude. The parallels and meridians are further used as state or international boundaries and even for laying out the streets and lots of a city.

Meridians and the Sun. — We said that meridian meant "midday" line. When the sun is just above a north-south line passing through New York, we say that it is noon in New York. This line would pass, if extended, through the two poles. The earth must rotate on its axis before the sun reaches our meridian again, twenty-four hours later. Every place east or west of us is on a different meridian from ours, and has its noon at a different time, since the sun cannot be over more than one meridian at a time as the earth rotates beneath it. All meridians to the east of us get the sun or have noon before we do, and places to the west have theirs later. We have already learned that there are 360 meridians.

Longitude and Time. — Since it takes the earth twenty-four hours to make a complete rotation on its axis, the sun in that time seems to pass over 360° of the earth's circumference. In one hour, then, the sun seems to pass over one twenty-fourth of 360°, or 15° of the earth's circumference. If this is true, points which are 15° apart will vary in time by one hour. In the United States, for example, the sun's rays fall upon the Atlantic coast more than three hours sooner than upon the Pacific coast. The reason, of course, is that the earth rotates from west to east. When New York boys and girls are going home at three o'clock, pupils in San Francisco are just being dismissed for luncheon, since the sun shows that it is only twelve o'clock in the western city. When San Franciscans are reporting to school at nine o'clock, New Yorkers are going home for luncheon.

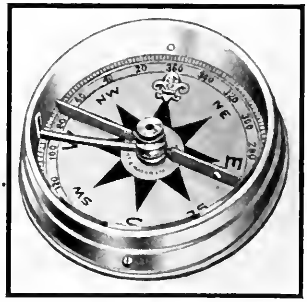


FIG. 64. A pocket compass.

The Compass. — On the bridge of every ship in plain view of the steersman a **compass** is always found. This instrument is of great importance in determining directions on the earth. It consists of a bar of magnetized steel or of several needles so suspended that the bar or the card to which the needles are attached will swing freely in a horizontal plane. It is constructed of a copper or brass bowl, hemispherical in shape, into which is mounted the compass card fitted upon a delicate point, the dial revolving upon an agate cap to

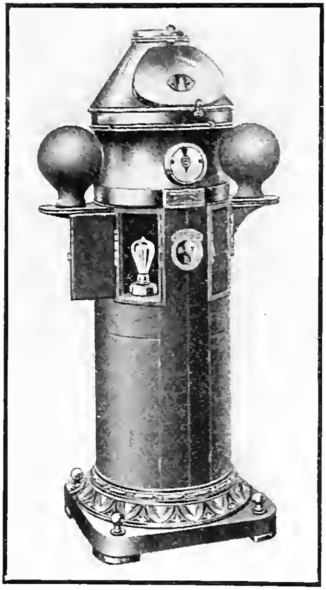


Fig. 65. A ship's binnacle or compass stand.

insure its working easily. As the roll and pitch of a vessel would be liable to unsettle the ordinary compasses, these bowls are usually fitted with some alcoholic liquid to keep the card steady. The needles always point north and south, regardless of the position of the ship.

The compass does not point to the geographical pole but to the **north magnetic pole** in northern Canada (70° north latitude, 97° west longitude). By knowing how much the compass varies from the true north, however, the direction of the north pole can always be learned. The amount of this magnetic variation is called declination, and the navigating officers of vessels are always provided with government charts which show the exact amount of declination they have to make allowance for anywhere on the earth. Without the compass, navigation on the seas would be almost impossible. A land compass, much smaller than a ship's compass, is of great value to explorers, lumbermen, hunters, and surveyors.

Fig. 66. Officers taking the altitude of the sun by means of the sextant.

Longitude at Sea. — The navigating officers when at sea are careful every day to take the elevation of the sun with an instrument called the **sextant.** In this way they can tell when it is exactly noon wherever they may be. Every ship carries a chronometer or clock which gives Greenwich time. By

means of this time, the officer can learn how far east or west of the prime meridian he is, or in other words he can get the longitude of the vessel. For example, suppose the Greenwich time is 8 o'clock and the ship's time 12 o'clock. There is a difference of four hours. Since a difference of one hour in time corresponds to a difference of 15° in longitude, this ship must be in 60° east longitude. The longitude is east because the time by the sun is later than the time by the chronometer. If these facts were reversed, the longitude would be 60° west.

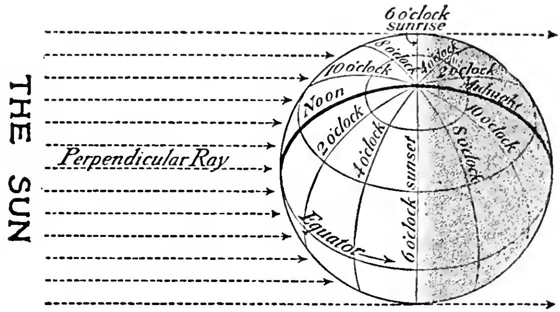


FIG. 67. The time on different meridians when it is noon on the prime meridian.

A Table of Longitude and Time.

360°	of longitude	corresponds	to	24 hours	of time.
15°	"	"	"	1 hour	"
1°	"	"	"	$\frac{1}{15}$ hour or 4 minutes	of time.
15′	"	"	"	1 minute	of time.
1′	"	"	"	$\frac{1}{15}$ "	" "
15″	"	"	"	1 second	" "
1″	"	"	"	$\frac{1}{15}$ "	" "

The International Date Line. — If a man starts westward from Greenwich to travel around the world, he must set his watch back one hour for every 15° of longitude passed over if he wishes to have the correct local time. This would require twenty-four changes during the journey around the world and thus he would lose twenty-four hours, or a whole day.

If he starts eastward from Greenwich, he would set his watch ahead twenty-four times to have correct local time and thus he would gain a day.

"As we pass to the east, the time doth increase;
As we pass to the west, the time doth grow less."

To overcome such differences of the extra day, the nations in 1884 agreed upon a place where time shall be changed. That place is the 180th meridian east and west from Greenwich, or the **International Date Line.** This line has been drawn so that no two neighboring regions belonging to the same country shall have different dates at the same time. This accounts for its irregularity on the map. Suppose that two men start from Greenwich, one going eastward and the other westward. The one traveling eastward will find the time at the 180th meridian twelve hours later than when he started, while the one traveling westward will find the time there twelve hours earlier. So the latter on crossing the line on Sunday must call the day Monday; while the one traveling eastward in crossing the line on Monday must call the day Sunday.

The International Day begins immediately after the stroke of midnight in London. The sun is then passing the meridian of 180° and it is noon at Rat island. Suppose that midnight of December 31 has arrived in London, and immediately January 1 has begun there. Is it, at Rat island, the noon of December 31 or of January 1? We know now that it is the noon of December 31 until the sun reaches the 180th meridian. Immediately upon the sun's passing that meridian, it is the noon of January 1 at the edge of the eastern hemisphere; and it becomes noon at each successive meridian as the sun reaches it, till the 180th is reached again twenty-four hours later. Locate the International Date Line on the map on pages 64, 65. Between Berlin and London a change of date from December 31 to January 1 would work confusion; none is likely to arise between the Primorsks and the Alaskans, nor between the Aleuts and the Kamchatkans, neighboring people having different dates and little commerce.

It is interesting to know that the Fourth of July begins at Guam island in the Pacific at about 9:30 A. M., and at Manila at 8 o'clock in the morning of the International Day. It is then 7 P. M. of July 3 in New York. The New York boy, then, is not far ahead of time when he begins to celebrate the Fourth at 7 o'clock the evening before.

Standard Time. — We saw that a difference of 15° in longitude between two places corresponded to a difference of one hour in time. If you traveled from New York to St. Louis, you would find

that your watch was one hour fast in that city. If you went on to Denver, you would find your watch was two hours too fast, while at San Francisco your time would be three hours ahead of the time of the clocks in the western city. Each place in between these cities would also have its own local time, or sun time. When the sun is

FIG. 68.

in the meridian of any town, it is 12 o'clock, noon, and at all places east of that line, it will be later and at all places west of it, earlier. The time of cities a few hundred miles apart, east and west, used to differ in this way by twenty minutes, thus causing great confusion in time-tables and train management. Starting westward with Boston time, trainmen found a time different from their own at Albany, at Buffalo, at Detroit, and at Chicago. Travelers' watches were always wrong. To avoid this difficulty, our continent has been divided into belts, and hour-meridians were selected, 15° apart, as shown in *Figure 68*; and within each hour-belt the time of the central meridian was adopted by all the towns and the railroads. These divisions are called **Standard Time Belts**; the Atlantic, central meridian 60°; the

Eastern, 75°; the Central, 90°; the Mountain, 105°; and the Pacific, 120°. Atlantic time is four hours earlier than London time, and Pacific time is eight hours earlier. In going from New York to Chicago, the traveler sets back his watch one hour from eastern to central time. If he starts from New York at 12 o'clock, in twenty-four hours he reaches Chicago at 11 o'clock, when the sun has just reached the meridian of New York and one hour before it will reach the meridian of Chicago. On his return, if he reaches Pittsburg at 12 o'clock, central time, he immediately starts for New York at 1 o'clock, eastern time; for every 15° difference the watch is set one hour ahead.

The boundaries of the time belts are irregular, because time is not changed on crossing the margin of a belt but at the nearest important railway center. In passing from eastern to central time, the change is made at Buffalo, Pittsburg, or Atlanta, as these are the principal cities that lie on the boundary between the eastern and the central time belts. Railway time-tables show a change of one hour at these points.

STANDARD TIME OF THE WORLD. — In 1913, at the International Conference of the Hour, the delegates of twenty-four countries met in Paris to sign an agreement establishing a standard time of day for the whole world. They decided on Paris as the point from which reckonings are to be made.

The idea is the same as the one we studied as United States Standard Time. The globe will be divided, as shown in *Figure 69*, into twenty-four sections, each named by a letter of the alphabet, and each corresponding to a difference in longitude of 15 degrees. In this way the difference in time between any two adjacent sections will be one hour. Section U in which Paris is situated will be taken as the one from which standard time will be measured. Every day at midnight and at 10 A. M. Paris will send out wireless signals all over the world. This will be of great benefit to navigators, since for the first time in history they will be enabled to correct errors in their chronometers and thus determine the position of their ships with a greater degree of accuracy than has ever been possible before.

In addition to the signals from Paris, others will be sent out at different hours from other stations. Some of the latter, including that at Norddeich, Germany, are already in operation. It has been arranged that signals shall be flashed from these other stations at the following hours each day: Arlington observatory, U. S. A., 3 A. M. and 5 P. M.; Manila, 4 A. M.; Mogadiscio, Somali coast, Africa, 4 A. M.; San Fernando, Brazil, 2 A. M. and 4 P. M.; Timbuktu, 6 A. M.; Norddeich, Germany, noon and 10 P. M.; Massaua, Africa, 6 P. M.; San Francisco, 8 P. M. Navigators, explorers, and others will be able to get the exact standard time from one of these stations at least once a day.

Beginning at 9:57 A. M., twenty warning signals will be sent out by wireless, the last one ending exactly at 10 A. M. When the last signal is picked up by a wireless

apparatus anywhere in the world the operator will know that it is exactly 10 A. M. by standard time in Paris.

We have seen how the distance traveled by a ship each day is found by comparing the local or ship's time with Greenwich time, the ship's time being determined by the position of the sun or stars and the Greenwich time by the vessel's chronometer. From this it will be noted that the difference east or west between any two places is merely the difference between the two local times expressed in degrees. No way has ever been found, however, for making a ship's chronometer keep exactly correct time. At times

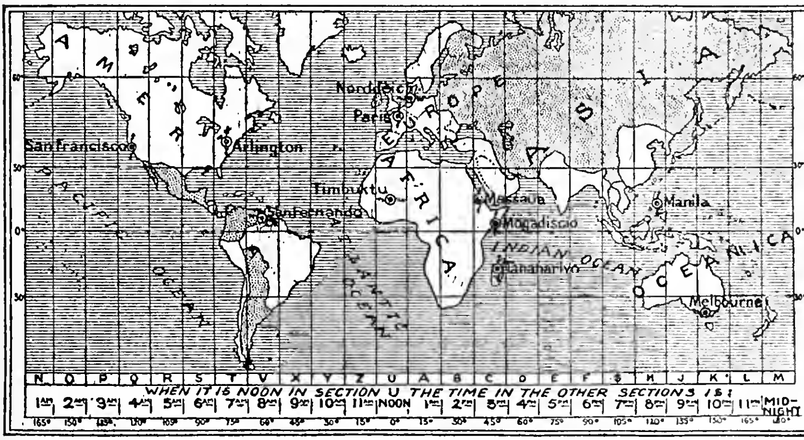


FIG. 69. A map showing the proposed standard time belts of the world.

the clock's error is such as to render the accurate finding of the ship's position impossible; and in such cases when the vessel is near land, disastrous results may follow. With the scheme of the International Conference the wireless signals will act as a check on the chronometers. The great importance of this may be realized when it is remembered that an error of one second in calculating the time at sea means an error, in determining the ship's position, of something like 1,000 feet.

QUESTIONS. — (1) Why is it necessary to divide degrees of latitude and longitude? How are they divided? (2) Explain the importance to man of latitude and longitude. (3) When it is noon at New York, what time is it on a meridian 15° to the west? To the east? (4) When it is noon at Charleston, South Carolina, what time is it at Pittsburg? (5) When it is sunrise in New York, is it before or after sunrise in Buffalo, Galveston, Los Angeles? (6) How many hours elapse while a point of the earth's surface turns through 360°? 180°? 90°? 30°? 15°? (7) Of what use is the compass to man? (8) Describe the compass you would see on a ship's bridge. (9) How does this differ from a pocket compass? (10) Why was the International Date Line established? Why is it not straight? (11) Name the time belts in America and locate each. (12) How is the time for each determined?

EXERCISES. — (1) When it is 7 o'clock in the morning in New York, what time is it in Chicago? In San Francisco? In Manila? In Rome? In London? (2) When it is noon by the sun, a ship's chronometer shows the time at Greenwich to be 4 o'clock. Find the ship's longitude. (3) Suppose at noon the chronometer shows the Greenwich time to be 6:30 A. M. What is the longitude? (4) What time is it now at Greenwich? At Buenos Aires? At Tokyo? At Colon? At Panama? (5) If you were going home from New York to Salt Lake City, where would you change the time of your watch? (6) Where and how much would you change your time in traveling from Los Angeles to Chicago?

CHAPTER VI

THE MOON; ITS REVOLUTIONS AND PHASES

Facts about the Moon. — In Chapter I we referred to the fact that when our universe was in process of formation many ages ago, the satellite known as the moon was thrown off from the earth. Astronomers tell us that the moon, if forced into the same shape, would quite fill the great gash in our planet's face: the bed of the Pacific ocean. The moon's diameter is about 2,160 miles, and *Figure 70* shows us the circumference of the satellite as compared with the size of Europe. We must not be confused by the apparent size of the moon, which often seems to be the largest of all heavenly bodies visible. The fact is, however, that the moon is the smallest of all the heavenly bodies visible to us, the stars appearing very small on account of their great distance. In shape it is spherical like the earth, and it, too, is slightly flattened at its poles, due to its rotation.

FIG. 70. Relative size of Europe and the moon.

A cord long enough to be wrapped ten times around the earth at its equator, would be long enough to reach from the earth to the moon. A railroad train which could encircle the earth in twenty-seven days could, if going at the same speed, reach the moon in thirty-eight weeks. This distance is about 240,000 miles, as an average. But, just as the earth's orbit around the sun is not a perfect circle but an ellipse, so the moon's orbit is an elliptical path and its distance from us varies from 253,000 miles to 222,000 miles. The size of the moon is one-forty-ninth that of the earth, but our planet

is eighty times heavier. It would take forty-nine moons united to form a globe as large as ours.

Surface of the Moon. — When the satellite is viewed through a telescope as shown in *Figure 4,* large flat areas are seen which some people think may have been the beds of seas in ancient times. We can see them with the naked eye as irregular dusky regions. Nearly two thirds of the surface, as we see it, consists of bright regions, which are broken and mountainous. The mountains of the moon generally surround enormous pits like volcanoes, as shown in *Figure 71,* but these differ in their great size from our volcanoes, since many are sixty miles across. In addition to these circular mountains there are several long and lofty ranges of moon mountains, very much like our Andean and Himalayan ranges.

FIG. 71. The mountainous surface of the moon.

We are unable to discern any trace of air or water on the moon, and we suppose consequently that there is no form of life on this great wanderer. The only changes seem to be those between heat and cold, and light and darkness. The moon, like the earth, has no light and little, if any, heat of its own; but its surface acts as a huge mirror in the sky and reflects or sends back, as *Figure 73* shows us, the light received from the center of the solar system.

We on the earth are never in a very great danger of being "moonstruck" since the light reflected from this mirror in the skies is only $\frac{1}{600,000}$ as strong as sunlight.

The Moon's Revolution and Rotation. — The earth is a satellite of the sun and the moon is a satellite of the earth. Just as the sun holds the earth in its orbit and forces it forever to swing around the parent body, so the earth through the force of gravitation holds

the moon in leash, and compels its satellite to make the circuit of its orbit once in every $29\frac{1}{2}$ days. It was the **revolution** of the moon around the earth in this period that formerly gave rise to the custom of measuring time by months (moons). As the moon revolves about the earth it also **rotates** on its axis, but, strange to say, it rotates so slowly that it requires $29\frac{1}{2}$ days also to complete even one rotation. We know that the much larger earth spins around on its axis once in every twenty-four hours. As a result of this condition, the length of a day on the moon is about that of one of our months, and the whole lunar year has only twelve days.

FIG. 72. The moon at the first quarter.

Place a spot of ink on a lead pencil and then revolve the latter around a book, the ink mark facing the book. Turn it on its axis so that, like the moon, it rotates once while making its revolution. You will notice that the spot of ink all during the trip continues to face toward the book. In doing this you have illustrated the monthly revolution of the satellite around the earth and its rotation in the same period of time on its axis. Our moon then turns the same face toward the earth. We always see the same "man in the moon," an appearance which is really the bottoms of dried seas. No one on the earth has ever seen the other side of the moon, and yet we know from the shadow it casts that the planet must be spherical.

FIG. 73. How the moon sends us its light.

Phases of the Moon. — As the moon travels

around the earth it shows itself, by the reflected light of the sun, in different forms. These are gradually changing from one shape into another and are known as the **phases** (appearances) of the moon. If it shone with light of its own, it would always appear circular to us, as does the sun. But we have every month the changes you have noticed, a new moon, quarter moon, half moon, and full moon. These phases are due to two causes: First, to the fact that the moon is opaque and can therefore be lighted only on one side at a time, as the eight positions of the moon in its orbit show in *Figure 74*. The second cause is the fact that the earth's orbit and the moon's orbit are not in the same plane. The moon's orbit is inclined to the earth's at an angle of over 5°, so that the moon may be on the same side of the earth as the sun and not be on the straight line connecting them. If you can imagine the sun in this diagram to be shining through the book from a point several feet behind it, you can see that all three bodies will not be in the same straight line. The moon therefore will be very unequally lighted up in its revolution around the earth.

1. **The New Moon.** — When the moon is in that part of its orbit which passes between the sun and the earth, as in 1, it has its back turned toward us, the illuminated side being toward the sun. It is then invisible, and this appearance is the true "**new moon.**" However, we always give this name to the narrow crescent-shaped figure, which shows in the west, after sunset a few days later, as in 2.

2. **First Quarter.** — The crescent gradually enlarges into a half circle as the moon passes away from the sun and we see more of its lighted face. This half-circle appearance or phase, which occurs when the moon arrives at a position in the sky at right angles to the direction of the sun at 3, is called the "**first quarter.**"

3. **Full Moon.** — The moon in 4 begins to move around behind the earth so that our planet is between it and the sun. No light at all now would reach the moon except for the fact that since the orbits are not in the same place, the sun, earth, and moon are not in a straight line. When the satellite has arrived just behind the earth its whole face, lighted up, is turned toward the earth. This phase, number 5, is called "**full moon.**"

4. **Last quarter** — Now the moon returns around the other part of its orbit so that, at 6, its face grows smaller and, at 7, it assumes the appearance of a half circle. This is the "**last quarter.**" Then comes, at 8, the crescent shape again or "old moon," and finally

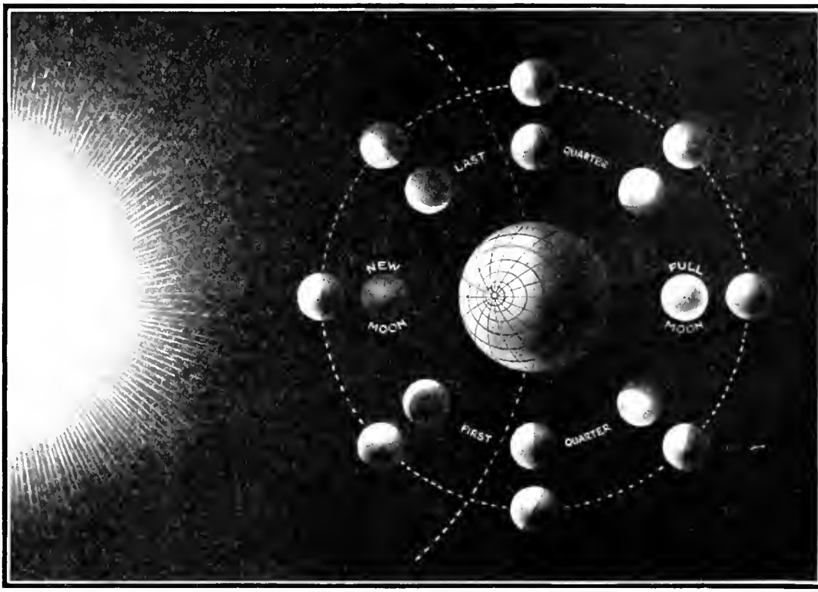


FIG. 74. The phases of the moon. The outer circle shows the moon as seen from the sun. The inner circle shows the moon as seen from our earth.

it disappears to become a new moon once more. This trip has taken it just 29½ days.

You can imitate the moon phases very clearly by taking an orange and placing yourself several feet from an unshaded lamp. Sit on a piano stool in order to turn more easily. Hold the orange up in the light and cause it to revolve around you by turning yourself upon the stool. As it passes from the dark position between you and the lamp, you will observe the crescent new moon, the quarter, the full, and finally the old moon.

The Harvest and Hunter's Moon. — These full moons, which in some parts of the world give a helpful light after sunset, occur only

near the time of the autumnal equinox. The one nearest the date of the equinox, September 23, is the "harvest moon," and the full moon next following in October is the "hunter's moon." For several successive evenings they rise immediately after sunset almost at the same hour. This is due to the fact that the plane of the earth's orbit, from which the moon's path departs only by 5°, is, in the high latitudes, nearly parallel with the horizon.

We learned that in our winter the sun is low in the sky, being south of the equator. Since the full moon must always be opposite to the sun, it is always higher in the sky in winter and gives a brighter light then, than in summer.

Eclipses of the Moon. — You have noticed in *Figure 74* that there are times when the moon enters a position between the sun and

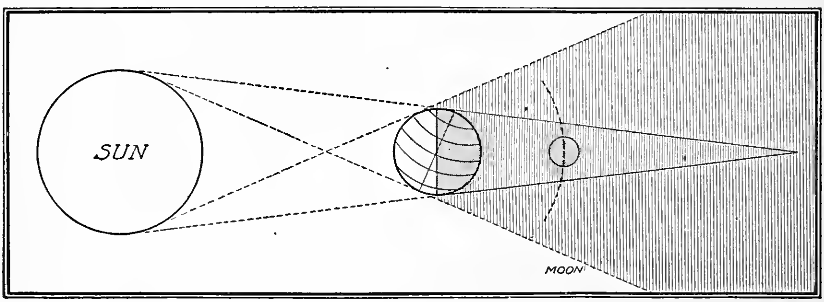


FIG. 75. An eclipse of the moon.

the earth, and times when the earth in turn shuts off the moon from the sun. Sometimes these positions of the bodies cause an **eclipse** or a "leaving out of light." You see from *Figure 75* that the opaque earth throws out a long conical shadow into space on the side away from the sun. The moon in its orbit must pass through the dark space in its monthly trip. While in the shadow, it receives no light, and is said to be in eclipse. These lunar eclipses would occur every month if the sun, moon, and earth were on a straight line, but as we have seen, the moon's orbit is inclined 5° to that of the earth. They occur only at time of full moon, and according to the deviations of the earth, the sun, and the moon from a straight line, the moon may

pass through the center of the shadow, or to one side of the center, or merely dip into the light edge of it. When it passes through the dark middle and is entirely covered we have a **total eclipse.** When only a part of the moon is darkened we have a **partial eclipse.** A total eclipse often lasts two hours and is visible from all parts of the earth then facing the moon.

Eclipses of the Sun. — In this case the moon causes the eclipse by hiding the sun from the earth. Here again, to have an eclipse the three bodies must be in a straight line drawn through their centers. The moon often passes between earth and sun, above or below this line, so that no eclipse occurs. However, an eclipse may occur even if the moon is not in an exact line with the sun and earth. We have seen that the distance of the moon from the earth varies from

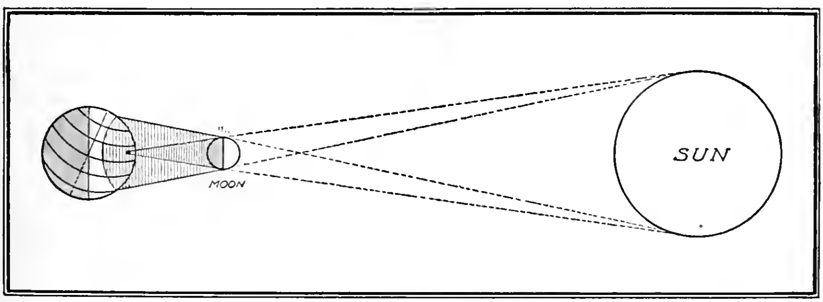


FIG. 76. An eclipse of the sun.

222,000 to about 253,000 miles. The moon then is sometimes at her greatest distance from the earth at the moment when she passes centrally over the sun, and sometimes at her least distance, or she may be at any intervening distance. If she is near the earth her surface just covers that of the sun and we have the **total eclipse.** If she is at the greater distance her disk seems smaller to us on the earth, and she does not seem to cover all the sun but leaves a rim of the sun visible all around the moon. This is called an **annular** (ring-shaped) **eclipse.**

You notice how small the moon's shadow becomes before it touches the earth (*Figure 76*). This spot is never larger than 165

miles in diameter and generally much smaller. It moves across the earth in a west to east direction, taking at the most only eight minutes to pass any point on the earth and often passing in two minutes. The true eclipse is visible only to those people living where the central shadow falls on the earth, but the partial phases of the eclipse may be seen from places aside from the track of the central shadow. From the regularity of the movements of the members of the solar system, astronomers are able to predict eclipses years in advance. On the average, we may observe over the whole earth seventy eclipses in eighteen years, twenty-nine of the moon and forty-one of the sun. There can never be more than seven eclipses in one year nor less than two.

Effects of the Moon on our Earth. — We learned about the force of gravitation possessed by the earth. The moon also possesses this power of attracting other bodies to itself, so that it keeps up a constant pull on the earth, just as the earth pulls on the moon. Every atom on the earth feels this pull of the moon, but all do not obey it. The solid land resists the gravitational force of the moon, but the drops of water on the earth making up our oceans yield in a certain measure to its influence. We are to see later what the effects of this moon-pull are.

QUESTIONS. — (1) Why is it that only one side of the moon has ever been seen from the earth? (2) How are we certain that the moon is a sphere? (3) Can you give any reason for doubting whether life exists on the moon? (4) Explain why the moon is not always visible from the earth. (5) If you should see the moon to-night from the city of Quito would it appear any different from its appearance when viewed from New York? (6) Why is it called a dead planet? (7) Give the simple meanings of the following words: **phase, eclipse, partial, annular, planet**. (8) What two causes produce the phases of the moon? (9) In looking at the moon, how can you tell whether it is in the first or last quarter phase? (10) When do we see the Harvest moon and the Hunter's moon? How did they receive their names?

EXERCISES. — (1) Write a paragraph describing the surface of the moon as it would appear to a traveler from the earth. (2) Make a diagram of the moon revolving about the earth. Fill in all the dimensions and distances that you know. (3) Make a diagram showing the moon at the first quarter phase. Explain this appearance as seen from the earth. (4) Draw and explain the full moon phase. (5) Write a paragraph giving an imaginary account of the life of the moon from its beginning to the present. (6) Make a diagram to show a partial eclipse of the moon. (See *Figure* 18.) A total eclipse. (7) Make a diagram to show a partial eclipse of the sun. A total eclipse.

An annular eclipse. (8) What effect do you imagine the eclipses of the sun had upon the minds of people who did not understand their causes? (9) At what phase of the moon only can a solar eclipse occur? (10) Why can a lunar eclipse occur only at the full moon phase? (11) Draw a picture of the earth as it would appear from the moon. Would it be a light or a dark object? Tell the reason for your answer.

CHAPTER VII

THE EARTH'S ATMOSPHERE: DEW, FOG, AND CLOUD

Our Sea of Air. — We know that the atmosphere is a great sea of air forty miles or more in depth, which rests upon the land and the water. It completely envelopes the planet, as the earth rushes around the sun. The air is a mixture of invisible gases, of which oxygen, forming 21% of the whole, is the most important element. Nitrogen forms 78% of it, and then there are argon, carbon dioxide, and water vapor present. The nitrogen serves merely to dilute the oxygen, since men and animals could not take pure oxygen continuously into the lungs. Animals inhale the air, take out much of the oxygen, and exhale the residue along with carbon dioxide, made up of one part of carbon and two of oxygen. Plants, which also breathe air in, have the power of separating these parts of carbon dioxide. They retain the carbon, and breathe out the oxygen.

The atmosphere then is one of the most important parts of the earth. Without it neither man as we know him, nor animals, nor plants could exist on the earth. Without it, no winds would blow, no fires would burn, no rain would fall, no climatic differences would be noticed, and the earth would be a dead planet like the moon.

The Thermometer. — The amount of heat in the air is measured by means of a **thermometer** (measure of heat). The ordinary thermometer is a graduated sealed glass tube terminating in a bulb and partly filled with a liquid metal called mercury. Notice the point marked 32° in *Figure 78*. When the atmosphere is cold enough to freeze water the particles of mercury draw more closely together so that the level stands just at this point. Should the instrument be placed in boiling water the mercury would expand and fill the tube to the 212° mark. Temperatures in the atmosphere generally vary between these two degrees of heat, though temperatures below the 0° mark on the scale are often recorded. This form of thermometer

is known as the **Fahrenheit**, after its inventor, and is the scale generally used in the United States and in England.

Summer temperatures ordinarily range between 76° and 100°. The colder temperatures of our winter are below 32° and a temperature lower than 0° is said to be below zero. Near the little town of Verkhoyansk in northern Siberia the average January temperature is 60° below zero (−60°) and temperatures of more than 90° below zero have been recorded. This region is the coldest known place in the world. On the other hand, in summer its temperature often is more than 95° F.

FIG. 77. A geyser in eruption. Note the condensation of the stream.

Formerly we believed that "the higher in the air the lower the temperature." From recent experiments we learn that the temperature at altitudes above eleven miles changes but slightly, and then to warmer. The lowest temperature that has been recorded high in the air is 85° below zero at fifteen miles. The highest altitude ever reached by a thermometer was 20.3 miles, where the temperature registered 48° below zero.

Moisture in the Atmosphere. — When the atmosphere above the earth is warm, it takes up and holds a great amount of water, in the form of vapor. The process by which liquid water becomes vapor is called **evaporation.** When vapor laden air is cooled, it cannot hold so much vapor and some of it is changed back into liquid water. The process by which a vapor becomes liquid water is called **condensation.**

We have all seen the moisture in our breath condense, so as to form a little cloud, when we are abroad in the cold air in winter. In a kitchen, when a kettle of water is heated over a fire, evaporation takes place, owing to the heat, and gradually the water disappears from the kettle, being changed into vapor. When, however, this

vapor strikes the cold window panes, it is cooled, becomes liquid, and trickles down the pane in little streams.

The quantity of moisture in the earth's atmosphere (its humidity) is measured by an instrument called the **hygrometer** (measure of moisture). *Figure 78* shows that the hygrometer consists of two thermometers, the bulb of one open to the air, while the bulb of the other is constantly wet, being covered with silk cord or wick immersed in water. When you leave the water after bathing, you are sometimes chilled, because, as water evaporates on the skin, it causes a loss of heat. In the same way, as the water on the silk cord evaporates, it will cause a loss of heat from the mercury and the wet bulb thermometer will read lower than the dry, providing there is a degree of dryness in the air. From the lower temperature we can ascertain whether the air is very dry or contains a fair amount of moisture. If the air is completely filled with water particles, both thermometers will read alike, as there can then be no evaporation.

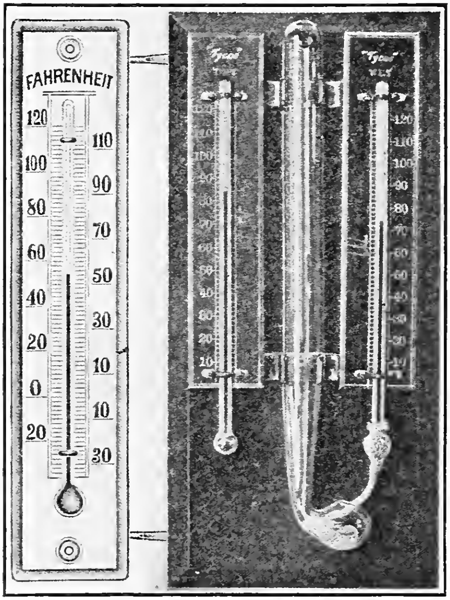


FIG. 78. A Fahrenheit thermometer. A hygrometer. Note the wet and the dry bulb.

Humidity. — The amount of moisture in the atmosphere, or its **humidity,** is of the greatest importance. Air without moisture could not sustain life, while air too dry causes ill health, catarrh, colds, and other diseases of the mucous membrane. Moist air is much warmer than warm dry air also, and humidity causes the temperature, as shown by the thermometer, to vary as much as 45° from the temperature as felt by our bodies. If it were not for the moisture in the atmosphere, it would be too cold to live in. The reason for this is that if the air is dry, the heat goes through it without warming it.

If the air is moist, it stops the heat and is warmed by it, so that humidity surrounds the earth like a great pall, keeping in its heat. If the air lacks moisture, we are obliged to secure more heat in order to feel comfortable. The dry air allows too much heat to escape from the body, and this too rapid evaporation, as we have seen, makes us feel cold.

Am. Mus. Nat. Hist.

FIG. 79. Securing cold drinking water in the tropics by first permitting evaporation to take place.

QUESTIONS. — (1) State why the earth's atmosphere is so important to man. (2) What determines the height to which an aeroplane can rise? (3) Tell how the temperature of the air is determined. (4) Tell how the humidity of the air is determined. (5) What changes might be observed if the earth had no atmosphere? (6) What results might be observed if the atmosphere lost its moisture? (7) Define evaporation and condensation. (8) Tell all the differences between the effects of dry and moist air. (9) Explain the gases of which the air is made up. (10) Make a diagram of a thermometer, marking the freezing and boiling points. (11) If the temperature in New York is 52° F., and the temperature in Tomsk is −48° F., what is the difference in temperature between the two cities? (12) Why do many people, when crossing the Rocky mountains, suffer from difficulty in breathing? (13) A balloon partly filled with a light gas was recently sent up in a government experiment. At an altitude of 23 miles it burst. Explain the reason.

The Formation of Dew. — When any part of the earth's surface begins to turn away from the sun at night, both the atmosphere and the land begin to get cooler. The ground gives off its heat faster and cools more rapidly than the air. In this way the lower air touching the ground is also cooled, and being unable to hold all its moisture gives up some of its vapor as **dew.** The temperature at which moisture in the air begins to condense is called the **dew point.** In the tropics, where there is a great quantity of vapor in the air, the amount of dew forming at night is very great. Sometimes the coolness of the late afternoon will wet the grass with dew even before

dark. Grass and leaves are covered with dew sooner than soil because they get colder more quickly. Again, because the air is more damp, dew is formed more readily near streams or swamps than in dry places.

All plants constantly give out moisture from their leaves. During the day this moisture is evaporated by the sun, but at night the evaporation is checked and as a result the moisture forms drops of water on the leaves. So that dew is the result of two processes, — the chilling of air by the cool ground, and the rising of water from plants. Dry air, winds, and clouds are unfavorable to the formation of dew: dry air, because it does not contain sufficient moisture to give up any of it; winds hinder the formation by carrying away the moisture as soon as it is condensed; while clouds pressing down upon the air and the earth prevent the earth from giving up its heat quickly enough to make the air condense by becoming colder than the earth is. Clear nights are best for the formation of dew.

Frost and its Effects. — When the temperature of the air is below 32°, the freezing point of water, the vapor condensed from the cold air takes the form of **frost.** This is not frozen dew, but vapor that has become condensed as a solid, instead of a liquid. Dew refreshes all plants, and frost always injures them. Sometimes it comes so early in the fall that fruit not yet ripe is destroyed; and late spring frosts do great damage to buds. It also causes the autumn leaves to change color and to fall. A covering, such as a sheet, will prevent the formation of a light frost by keeping the heat in the ground and thus delicate plants may be protected.

It is very important for farmers and fruit growers to know when a frost is expected. They are warned from twenty-four to thirty-six hours in advance by the United States Weather Bureau. The value of the orange bloom, vegetables, and strawberries saved in a single night in a limited district in Florida by these warnings was over $100,000. Fires are often built in orchards of delicate fruits, or many lamps are lighted to protect the weak buds from the drop in temperature.

Fog: Its Causes and Effects. — When we breathe into cold air, we produce a tiny **fog.** The tiny drops of water vapor are so light that they do not fall to the ground but hang suspended in the air.

Fog is always formed when damp air is cooled. It often forms at night when the air over low, damp ground is chilled to the point that it has to give up some of its moisture. It is often caused at sea by two currents of air meeting, one cool, the other warm and damp.

Fogs will form around an iceberg because the air near it is chilled, over the surface of a lake, and in damp valleys. On the banks of Newfoundland they are common in summer, because the warm air from the Gulf Stream strikes the icy winds blowing over the Labrador current and is condensed (see *Figure 122*). These and other ocean fogs often extend upon the land, as in Maine and Nova Scotia.

On the Atlantic from 30° to 35° north latitude, fogs are almost unknown. But during the month of July the water on the banks frequently has a temperature of 45° F., while within a distance of less than 300 miles the Gulf Stream has a temperature of 78° F. The fog of London is sometimes so dense, due to water collecting on millions of dust particles in the air, that traffic is stopped and stores are closed.

Fog is one of the most dreaded dangers of the sea, and careful captains reduce speed and sound fog horns to warn other vessels of their approach. Many ships have been lost in fogs by collision with another ship or, like the ill-fated Titanic, with an iceberg. *Figure 120* shows a freighter which ran aground on shoals during a fog when her captain was unable to get his bearings.

At times the air is filled with small particles of water, which are larger than those in a fog and which cause greater dampness. We say then that it is "**drizzling**" or "**misting.**" The mist is a form of condensation midway between fog and rain, and possibly it is made of numerous fog particles which have united. Fogs and mists are usually seen in the morning when the surface of the earth is cooled. When the sun rises and warms the earth and the air, they change to invisible vapor. All mists and fogs, being heavier than lower levels of the atmosphere, tend to settle down through the air to the earth. But when they reach the warmer layers of the atmosphere they are evaporated again and disappear.

Clouds: Their Formation and Classes. — Clouds are also formed by the condensation of invisible vapor. They are composed of particles of moisture, made of fog or mist and, in many cases, of

Fig. 80. Cirrus clouds.

Fig. 81. Cumulus (woolpack) clouds.

Fig. 82. Strato-cumulus clouds.

Fig. 83. The nimbus or rain cloud.

snow or ice particles. In summer many clouds are formed by the rising of warm, damp air. As this rises, it expands and cools and, when it can no longer hold all its moisture, fog particles grow, forming clouds. When damp air is blown against a cold surface, for example, a mountain slope as in *Figure 164*, it has its temperature lowered below the dew point, and banner clouds, which extend beyond the peaks, are formed. Finally, when two currents of air meet, one being low and warm, the other cold and high, clouds are formed. This seems to be the cause of many of the magnificent clouds we see in the upper atmosphere.

Cloud formations are of many different kinds and are known by various names. The **cirrus** cloud (*Figure 80*) is the highest form known, its elevation often being over six miles. It is formed of many feathery forms of fine texture, generally white in color. It is so high that the condensation of water forms ice particles, which cause these clouds to appear thin and transparent. They drift along rapidly and often look like rings around the sun and moon.

The **cumulus** (*Figure 81*) are among the most stately and beautiful of cloud forms, particularly when lighted by the rays of the setting sun. They are produced at lower elevations than the cirrus and are generally composed of fog particles, rather than ice particles. They rise from a flat base about a mile above the earth and extend above this several thousand feet. The rising of air on warm summer days is usually the cause of these woolpack clouds, and the broad base shows us just where the vapor begins to condense. Frequently they develop into thunder heads. They are formed over land more readily than over water, and their formation often indicates to the navigator the presence of land.

The **strato-cumulus** clouds resemble the cumulus, but differ from them in being more massive and banded (*Figure 82*). They are large balls or rolls of dark cloud, which frequently cover the whole sky, especially in winter, and give it the appearance of layers or strata. Their elevation varies from 500 to 3,000 feet, but sometimes they are low enough to touch the earth.

The **nimbus** is the rain cloud. It consists of dense masses of dark formless clouds with ragged edges, from which generally continuous rain or snow is falling. Sometimes the nimbus is torn up into small

patches, so that these float along much below a great nimbus. Sailors call these "scud" clouds.

Many varied forms of cirrus clouds are recognized and various names are given to them. Sometimes they are frayed and torn by air currents. At other times they occur in bunches, arranged often in lines, as if produced by the waves of the air, the groups of clouds resembling a choppy sea. The name **cirro-cumulus** is given when these bunches of upper air clouds are distinct (*Figure 85*). When the sky is speckled with these cloud forms, sailors call it the mackerel sky. These formations are a kind of fleecy cloud, — small white balls and wisps without shadows, — arranged in groups or rows.

The **alto-cumulus** or high cumulus is a dense fleecy cloud, grayish balls being grouped in flocks or rows as in *Figure 86*, frequently so close together that their edges meet.

Snow. — Snowflakes are not frozen raindrops, but when the vapor in a cloud is forced to give up its moisture at temperatures below 32°, or the freezing point, the vapor crystallizes as it condenses and **snow** results. *Figure 84* shows some of the very odd and fantastic forms which the snow crystals assume during the change from vapor to solid. The same storm may produce snow on a mountain range and rain down below in the valleys, owing to the difference in temperature between the two places. The temperature is 1% colder for every three hundred feet of ascent. Oftentimes rain in winter is due to the fact that the snow crystals have been melted in their downward passage. Damp clinging snows fall before they are completely melted into water. Heavy snows cause great damage to railroads and force them to maintain a snow-fighting equipment. On the great western ranches, thousands of head of live stock frequently perish in the blizzards or northers, as the falls of heavy snow are called,

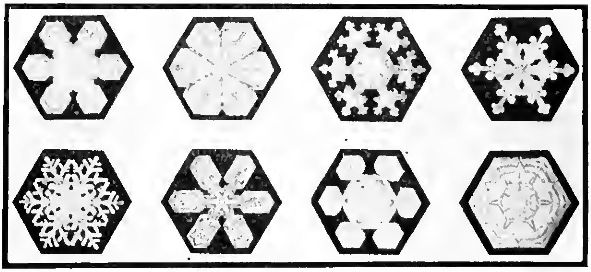


FIG. 84. Snow crystals.

Fig. 85. Cirro-cumulus clouds.

Fig. 86. Alto-cumulus clouds.

before they can be hastened from the ranges to shelter. In large cities, traffic is interfered with by snow, and great expense is incurred in clearing it from the streets.

Hail. — Balls of ice, called hailstones, sometimes fall from the clouds, generally during thunderstorms or tornadoes. They are usu-

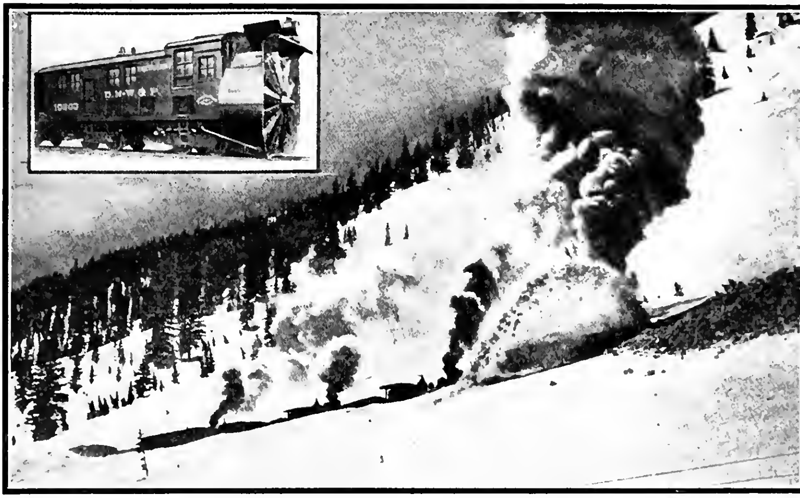


FIG. 87. A rotary snow plow clearing a railroad track in the west.

ally oval or rounded in form, and are often made of successive shells of clear and clouded ice. We know that the temperature of the air is not uniform, but that there are warm and cold currents running through the atmosphere. When vapor condenses above 32°, rain is formed. When the condensing drops of vapor fall through layers of air below the freezing point, the water is frozen. As the stones are whirled through different currents of air, they freeze and melt and freeze and melt, so that the stone, like an onion, takes on different layers or shells. They are sometimes an inch or more in diameter, and heavy enough to break windows and do great damage to crops.

QUESTIONS. — (1) Explain under what conditions dew is formed. (2) What part do clouds play in this process? (3) How is it that no dew forms under a newspaper left by chance on a lawn over night? (4) What benefit does the earth derive from dew? (5) Explain the difference between dew and frost. (6) How may the effects of frost

be offset? (7) State the cause of fogs blowing over New York City. (8) Write as many effects of fogs as you can think of. (9) Explain the formation and effects of fogs in the Atlantic. (10) Write definitions of dew, fog, cloud, frost, mist, snow, and hail. (11) Explain the cloud formation seen in *Figure 29*. (12) Name the various cloud forms, and tell how each is produced. (13) Explain the difference between snow and hail. (14) Describe the effects of snow and hail on vegetation. (15) How is it that snow sometimes falls when the temperature is many degrees above 32° F.? (16) Account for the fact that no clouds form above deserts.

CHAPTER VIII

VOLCANOES AND EARTHQUAKES — GLACIERS

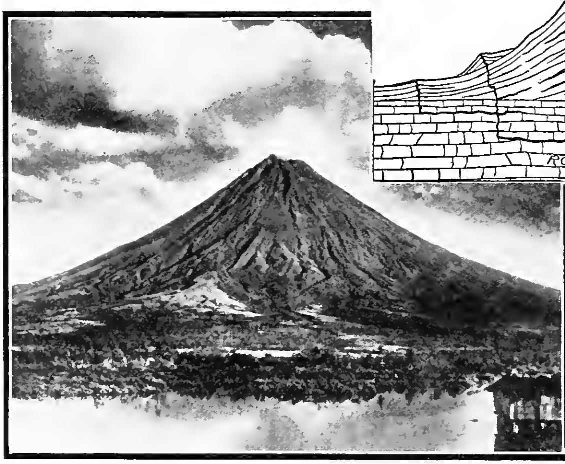
The Earth's Heat. — We have seen that when the earth came off from the sun, it was a glowing hot mass of cloud-like material which took the form of a sphere and flattened at the poles as it contracted in size. We believe that it has been revolving about the sun for at least one hundred million years. During this period it has been losing heat and cooling, but it is so large that many ages more will be required to make it completely cold, like the smaller moon.

From the fact that the deeper we go into a mine, the higher the temperature becomes; that volcanoes cast up molten rock; that hot springs bubble up, and that the crust is never at rest, — we believe that the interior of our planet is still highly heated. It was formerly believed that beneath a thin crust the interior was molten; but now it is thought that the centersphere, though very hot, is solid. It is solid, because the tremendous weight or pressure of the rocksphere upon the centersphere prevents it from melting, since much more heat is required to melt a substance under pressure than without pressure. At a depth of only five miles this pressure is great enough to crush rock; so that deep in the interior it is great enough to force all particles into a solid mass. The result of this condition is that whenever the tremendous pressure of the rocksphere is lessened or removed, the interior becomes a hot fluid mass and flows out on the surface.

Springs and Geysers. — The earth consists, then, of a thin, cooled, and solid crust surrounding a solid heated interior which is able to resume its liquid form. Through this thin crust, the earth water often passes in large amounts until, meeting the melted rock of the interior, it is heated to the boiling point. When this water flows to the surface again quietly it is called a **hot spring.** When it seems to collect for a while and gush out at regular intervals and often to great

heights it is called a **geyser** (*Figure 77*). Both springs and geysers carry mineral deposits which they sometimes deposit at the surface in beautiful forms. Certain hot springs in Virginia, Colorado, and Arkansas are famous health resorts, because the waters are full of dissolved minerals helpful in some diseases. Geysers are found in Yellowstone park, New Zealand, and Iceland.

Volcanoes. — Sometimes the waters of the earth passing down through the crust become heated very quickly into steam. This does not return at once to the surface but accumulates slowly under the strata. Finally the pressure that this pent-up steam exerts becomes so great, that the mixture of steam and hot water forces its way through the crust and carries some of the melted rock or lava with it. This lava may escape by flowing gently out upon the surface through fissures formed by the growth of mountains, or it may burst out suddenly in a volcanic eruption. The place where the explosion occurs is generally a spot where the crust has been weakened, so that the pressure on the heated interior is at once lessened. When this happens, the rock below is reduced to a molten condition again and rushes out. It forms about the opening, building a conical peak called a **volcano**. A young volcano is a perfect cone, because each eruption adds material to it. Sometimes, however, after a period of



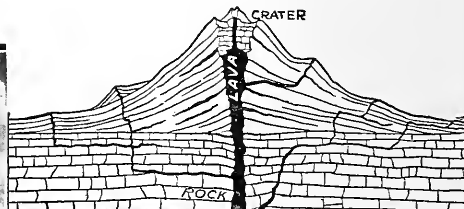


FIG. 88. A volcanic cone in the Philippines. FIG. 89. A section of a volcano.

Am. Mus. Nat. Hist.

FIG. 90. Mount Pelée belching forth steam and gases. Note the strange spine of lava which rose from the crater.

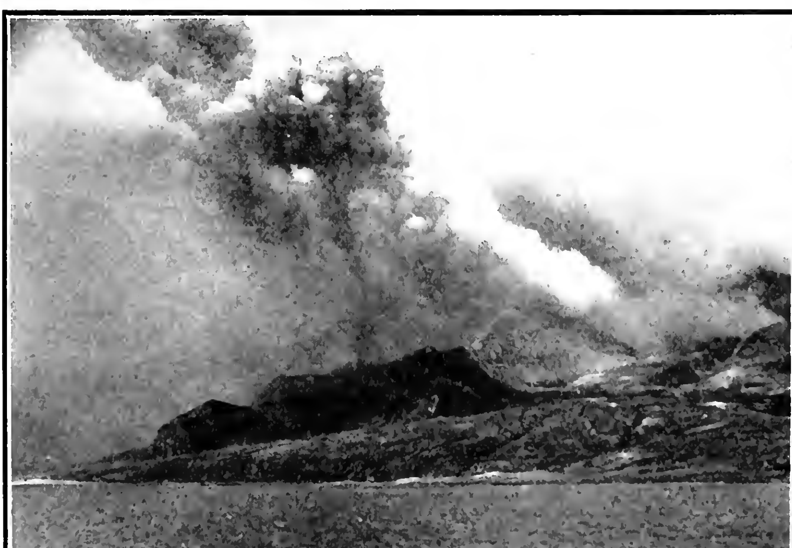


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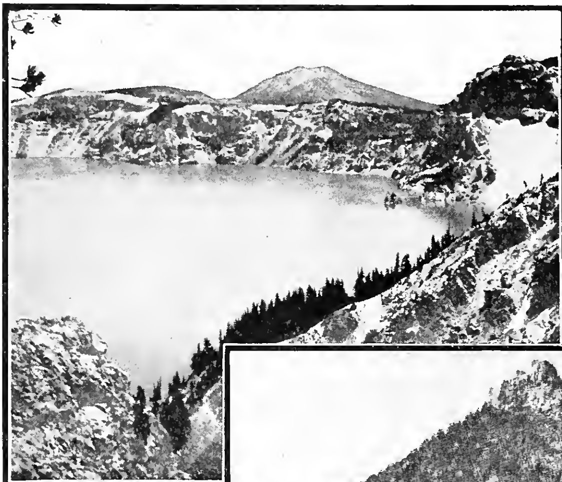
FIG. 91. Mount Pelée in full eruption.

quiet, an explosive eruption will blow off the top of the cone and produce a saucer-like depression called a **crater.** At the bottom of this is the **throat** of the volcano. In every eruption vast quantities of steam and sulphurous gases belch forth. The expansion of the steam often blows the lava to pieces, forming pumice and volcanic ash, which are often carried vast distances by the winds.

Not all the lava that starts toward the surface reaches it. Sometimes it fills up fissures in the rocksphere and hardens. Later, when the surrounding and overlying rocks have been worn away, these great lava sheets will be uncovered. In this way the Palisades of the Hudson were formed. Again, when a volcano becomes old and eruptions cease, the throat of the crater becomes choked with solid volcanic rock, forming a **volcanic neck** or plug. In its idle crater, rain often accumulates, forming a **crater lake.**



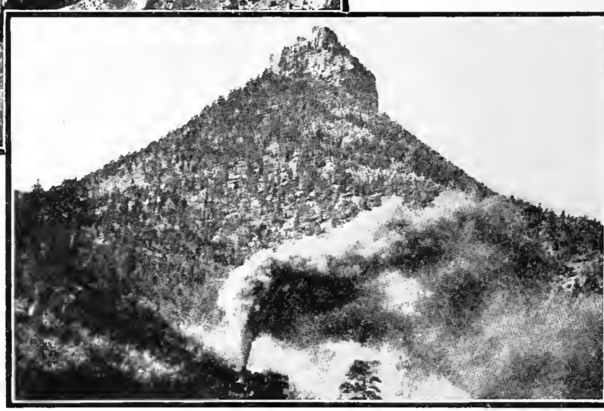


Fig. 92. Crater lake in Oregon, 2000 feet in depth. Fig. 93. A volcanic neck. Note how the other material is being worn down by erosion.

As soon as a volcano appears above the surface, the forces of ero-

sion and weathering immediately attack it to wear it down. The hases and soft lava forming the cone are worn away more quickly than the lava in the throat, and finally the lava plug alone is left rising above the surrounding country.

The Effects of Volcanoes; Mount Pelée as a Type. — Nothing in nature is more terrible than a volcanic eruption. The ash, lava,

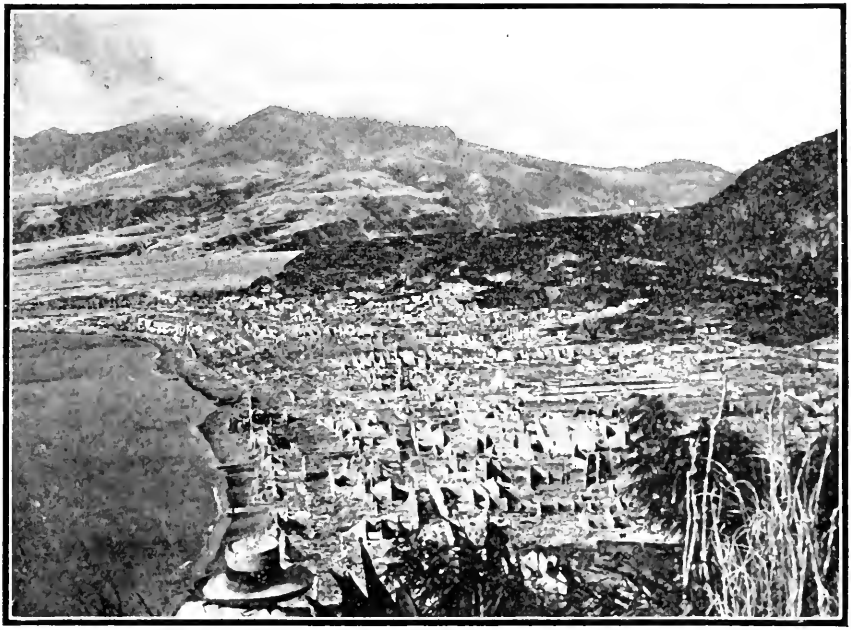


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FIG. 94. The ruins of St. Pierre. Mount Pelée is in the background.

steam, mud flows, gases, lightning, and earth shocks which accompany outbursts result in terrible destruction of human life, as well as animal and plant life. The last great eruption was that of mount Pelée on Martinique in the Caribbean sea, in 1902. The volcano had been slumbering since 1851. On April 25 warm water was reported in the old crater, later dust-laden steam issued, and finally on May 5 a lake of hot water and mud overflowed the crater and poured down the valley. After these warnings the eruption followed on

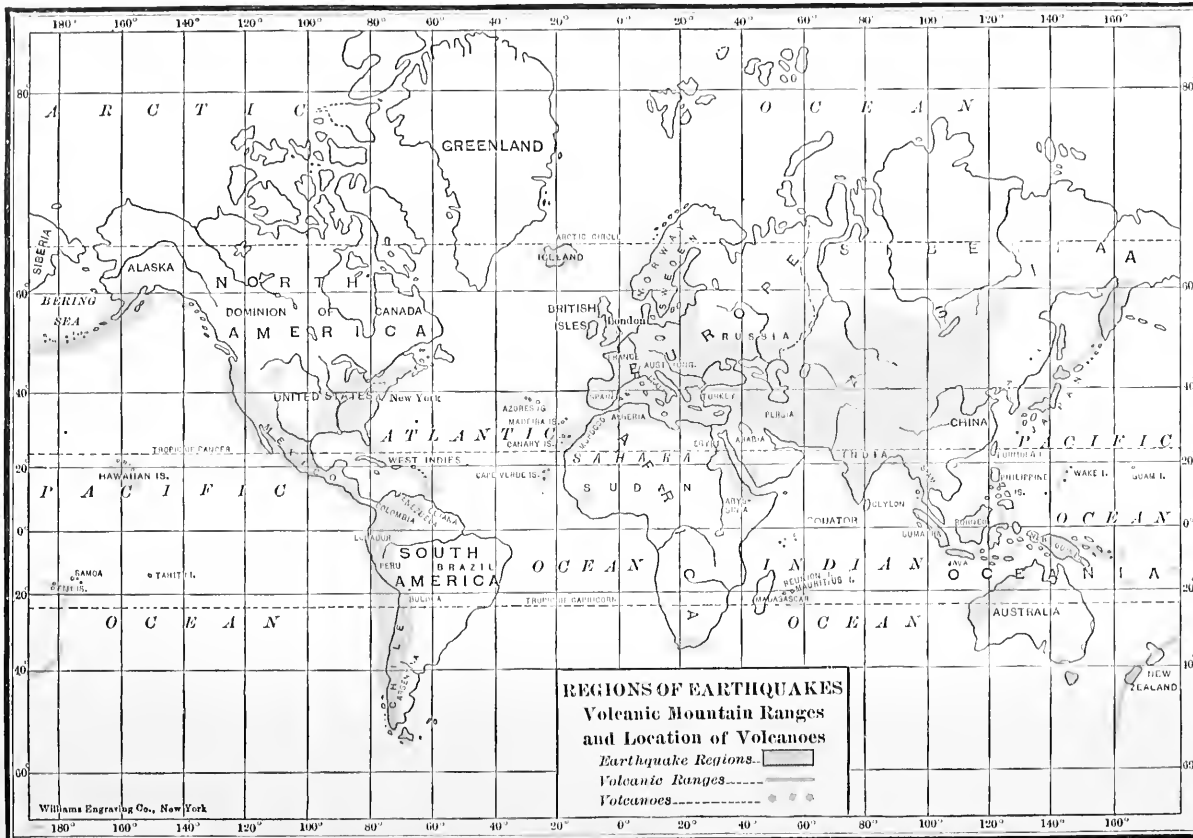
REGIONS OF EARTHQUAKES
Volcanic Mountain Ranges
and Location of Volcanoes
Earthquake Regions
Volcanic Ranges
Volcanoes
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
INDIAN OCEAN
NORTH AMERICA
SOUTH AMERICA
EUROPE
AFRICA
OCEANIA
GREENLAND
ALASKA
SIBERIA
BERING SEA
DOMINION OF CANADA
UNITED STATES
New York
MEXICO
WEST INDIES
ICELAND
BRITISH ISLES
London
NORWAY
SWEDEN
RUSSIA
FRANCE
SPAIN
TURKEY
ALGERIA
SAHARA
SUDAN
EGYPT
ARABIA
PERSIA
CHINA
AUSTRALIA
NEW ZEALAND
AZORES IS.
MADEIRA IS.
CANARY IS.
CAPE VERDE IS.
HAWAIIAN IS.
SAMOA
TAHITI I.
WAKE I.
GUAM I.
PHILIPPINE IS.
BORNEO
SUMATRA
JAVA
MADAGASCAR
PERU
BRAZIL
COLOMBIA
CHILE
ARCTIC CIRCLE
TROPIC OF CANCER
TROPIC OF CAPRICORN
EQUATOR
Williams Engraving Co., New York

FIG. 95.

May 8. A great cloud of steam burst forth bearing gases, ashes, dust, and rock high into the air. A break in the crater wall opened unfortunately into the valley leading to the city of St. Pierre, built on a narrow coastal plain. Along this valley the steam with its load of gases and hot rocks rushed like a cloud of fire, destroying everything in its path. Other outbursts, in all of which the lava seems to have been reduced to ash, have since followed this first one, and a cone 2,000 feet high has been built in the old crater. Ashes fell at sea 100 miles from the island. In the eruption 30,000 people were killed in a few seconds, and the city remains only as a blackened, desolate waste.

Am. Mus. Nat. Hist.

FIG. 96. Looking into the crater of a volcano.

The Distribution of Volcanoes.—Volcanoes vary widely in their eruptions. **Mount Vesuvius** in Italy, which destroyed Pompeii and Herculaneum in 79 A. D., has frequent eruptions, some violent, some moderate; some of ash, some of lava. **Stromboli**, between Sicily and Vesuvius in the Lipari islands, is always active. Originally it burst forth at the bottom of the ocean and formed an island. Every few minutes the steam in the crater erupts masses of lava and often throws molten streams of it down the sides of its cone. **Etna**, on the eastern end of Sicily, pours out lava streams every few years, and these make their way to the sea, destroying villages on the way. **Krakatoa**, near Java, in 1883, burst out with a roar heard 150 miles away. It produced a water wave noticed in Africa and California. The island was destroyed as a place of habitation and 35,000 people lost their lives through the effects of the eruption. **Hawaii**, the greatest volcanic mountain in the world, rises 30,000 feet above the sea floor and 14,000 feet above the sea level. One of its active vol-

canoes, **Mauna Loa,** is a crater three miles in diameter. In this the lava slowly rises and then freezes since the mountain is so high. No violent ash eruptions are known in this group.

We see then that volcanoes are found in all parts of the world. There are thousands of cones, but only about 300 are active, and these are generally in mountain regions near the sea. Notice how

Fig. 97. Destruction caused by an earthquake in the West Indies.

they encircle the Pacific ocean (*Figure 95*). In the western United States **mount Shasta, mount Hood,** and **mount Ranier** are types of extinct or old volcanoes. The Aleutian islands, Iceland, the Azores, St. Helena, and the Faroe islands are all volcanic in origin.

Earthquakes. — When mountains are being raised by the folding of the crust, the strata of the rocksphere often crack until the whole earth shakes from the blow. Volcanic eruptions also produce these earth shocks when steam forms in the craters and explodes them. Again we may imagine the interior of the earth cooling and shrink-

ing away from the rigid crust. The strata of the crust will break from lack of support and drop down to fill up the underlying gaps. All these shocks, felt for thousands of miles, are **earthquakes**. They may be so slight that they can be detected only by instruments called seismographs, or they may be so severe as to cause widespread destruction.

The center of an earthquake may be thousands of feet below the surface, but the jar from it will pass in all directions, diminishing in violence with the distance from the center. The ground may not rise and fall more than one inch and yet do great damage. The earthquake, however, is rarely a single shock, but generally a series of jars coming in such quick succession as to make one believe the ground is shaking. Sometimes 500 or more shocks are felt, an effect which is produced by the strata cracking and the rough edges slipping by one another.

We see from *Figure 95* that earthquakes usually occur in the volcanic regions of the earth. Those shocks that precede a volcanic eruption are due to the effects of the steam-filled lava breaking the rocks in its attempt to escape. The shocks are of frequent occurrence in Japan, Italy, Greece, and South America, though violent earthquakes have occurred in other regions.

The Effects of Earthquakes. — These shocks rival volcanoes in their destructive effects. They change the appearance of the earth's crust by creating great cavities which later become lakes; by opening deep cracks in the land through which pour great masses of steam and mud; by causing avalanches which dam streams and form ponds. In cities they produce death and devastation by overturning houses. In Japan people build their houses very lightly, generally of wood, one or two stories high, so that they may withstand ordinary shocks. Where cities are built largely of stone, as in San Francisco, great loss of property results. In that city, in 1906, an earthquake lasting only sixty seconds destroyed the business section of the city; while in Italy, at Messina in 1908, 100,000 people were killed as a result of the shocks. Earthquakes under the sea produce waves, slight in the ocean, but very high when they reach a low coast. In Japan and in the East Indies tens of thousands of people have been drowned by one of them.

GLACIERS

The Work of Glaciers. — On great mountain ranges, thousands of feet above sea level, enormous snow fields accumulate year after year, often to a depth of several hundred feet. The pressure of the upper layers and the alternate melting and freezing during summer days and nights changes the snow into ice, and gravity begins to draw

FIG. 100. The Rhone glacier in Switzerland. Note the valley it has dug out.

the whole mass down the mountain valleys in the form of a huge frozen river. As this mass moves, pressure and further melting and freezing gradually change it to pure, clear ice. Such an ice tongue, filling up a valley, is called a glacier. Some glaciers are fifteen miles long and may flow at a speed of about two feet a day. When, however, the front of the tongue reaches the lower part of the valley, the ice melts and a river is formed to bear the resulting water to the sea.

Every glacier, like a river, carries a burden of **detritus.** It bears

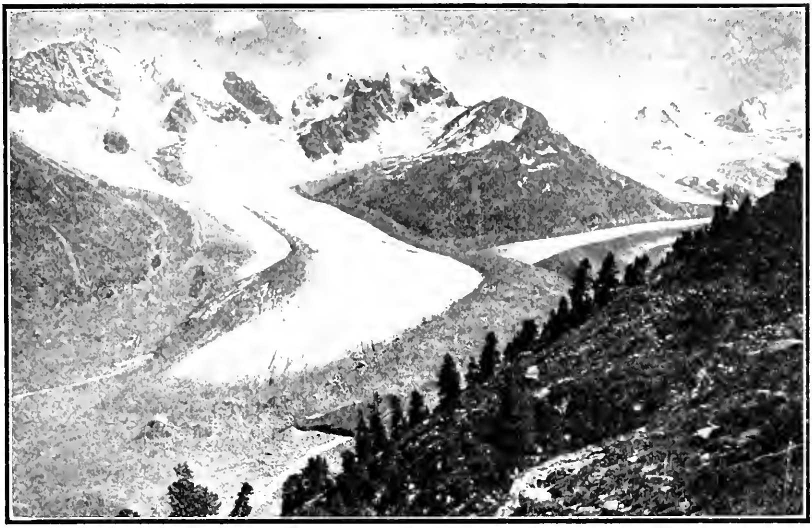

FIG. 98. Snow field and glacier with lateral moraines in the Alps.

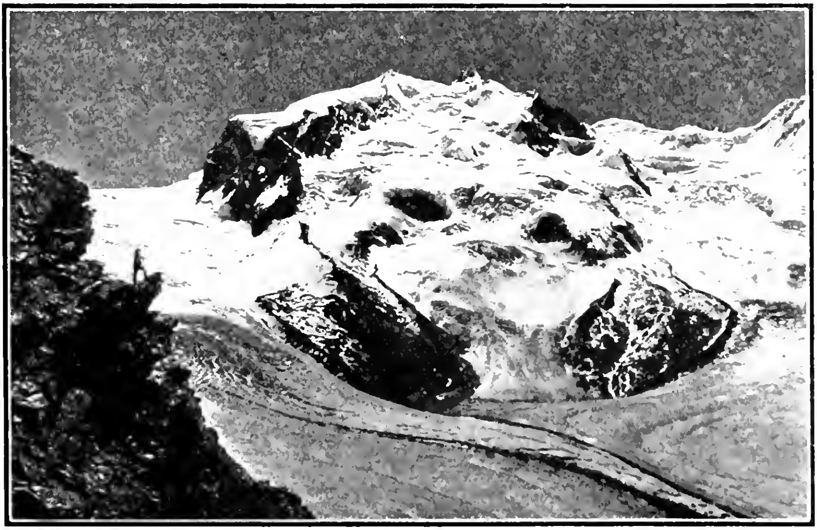

FIG. 99. Two glaciers joining, showing the formation of a medial moraine.

rock fragments fallen from the mountain sides, or ripped from its bed. These fragments, slowly dragged along and pressed down by the ice, groove and scour the rocks over which they pass. In this way again glaciers, like rivers, carry on erosion, deepening and broadening their valleys. The great bands of rock fragments which form on the sides of the ice river are called **lateral** (side) **moraines.** When two glaciers join, as in *Figure 99*, two lateral moraines unite to form a **medial moraine** near the middle of the glacier. The fragments frozen in the bottom of a glacier are called the **ground moraine,** and when a glacier has melted entirely away this ground moraine is left as a deposit on the valley bed. The advance of a glacier is limited by the melting of the ice as it reaches warmer levels, and at the end of the glacier all the detritus it carries, from fine rock powder to enormous boulders, piles up into a **terminal** (end) **moraine.** This may become 100 or 200 feet high, if the end of a glacier remains in one place for a long time.

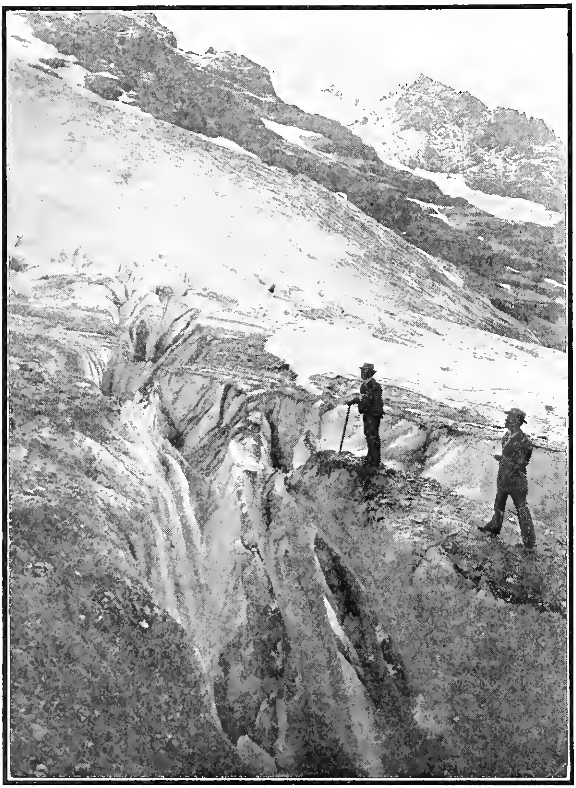

Fig. 101. A crevasse in a glacier.

When a glacier is subjected to a heavy strain it cracks, and openings called **crevasses** are formed in the ice. The irregular bottoms

of valleys are constantly producing these crevasses, so that the surface of a glacier is generally broken.

The Continental Ice Sheets. — It is thought that many thousand years ago some of the continents were so much more elevated than they now are that ice sheets covered them. Northwestern Europe and northeastern North America were ice-covered; a continental glacier extended from Canada, east of the Rocky Mountains, eastward and as far south as New Jersey. This ice sheet was thick enough to overreach the tops of mountains a mile in height. Evidences of its presence are found to-day in great north-and-south glacial scratches in rock, and in lake bottoms that were dug out by the ice. In the north central states great boulders are found that could have come only from Canada. Finally, the presence in these states of valleys widened and deepened by the ice, and of the ground moraine or glacial drift deposited on the surface when the ice melted, is further proof of the existence of the ice sheet.

New York, Pennsylvania, Ohio, and other states along the southern limit bear many signs, in soil, gravel, smooth rocks, and detritus, of the effects of this continental glacier. Thousands of lakes and waterfalls within the areas once covered by the glaciers of North America and Europe are due to the work of the ice. In New York and New England these have proved of great importance in developing manufacturing areas. The Great Lakes owe their depth largely to the scouring out of rock basins by the glacial ice, while Niagara Falls were a result of the glacial drift forcing the river out of its original course.

It is thought that after many thousand years the land lowered again, owing to movements of the crust, and that therefore the continents became warmer. Then the ice front slowly melted away, back northwards, leaving its burden behind. This work which it did in carrying, digging, scratching, and smoothing has led to the ice sheet being called a combined file, plow, and dump cart of immense size.

The Distribution of Glaciers. — The work these great ice sheets performed in changing the appearance of the land can be studied to-day in the work now being done by the smaller glaciers occupying the upper portions of river valleys in Switzerland, Alaska, Greenland, and the northwestern United States.

In Alaska the immense Muir glacier is fed by over twenty glacier tributaries. Its front is a cliff rising 200 feet above the water level and extending 800 feet below it. The great ice stream glides slowly down a broad valley and ends in the sea. There are nearly 2,000 valley glaciers in the Alps, and these serve as one of the attractions to tourists. High up in mountain valleys, glaciers are found even in Mexico. Baffin Land, Iceland, and Spitzbergen have many valley glaciers. Greenland, back of the fringe of coast land, is a great ice waste more than ten times the area of New York state. This great ice cap is sometimes called the Greenland glacier. The interior is often 8,000 feet high, and since snow falls there all the year round, there is a movement of ice outward toward the ocean in all directions. Antarctica also bears an enormous ice cap whose margin is a great ice wall rising several hundred feet above sea level.

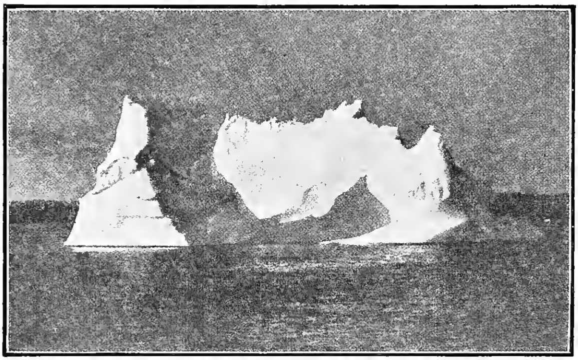

Fig. 102. An iceberg in the Atlantic.

The Formation of Icebergs. — All glaciers that extend down to the sea give off **icebergs.** The water, getting under the ice cliff, buoys it up, causing great masses to break off. Other masses are broken off by the water cutting out their under support until they snap off. The current of water from the glacier drifts them away from the fiords and, melting as they go, they deposit their rocky burdens along the sea-bottom.

QUESTIONS. — (1) Why do miners work in their shirt sleeves in the coldest days in winter? (2) How is it that melted rock issues forth from volcanoes when the earth's interior is so solid? (3) Explain the difference between a hot spring and a geyser. (4) Why do people spend weeks at the Virginia Hot Springs? (5) In what ways may lava rise from the heated interior of the earth? (6) How were the Palisades formed? (7) Why does the lava plug of the volcano in *Figure 93* rise as a peak above the surrounding country? (8) State the effects of volcanoes upon the earth and upon man. (9) Lo-

cate six large volcanoes. Locate the volcanoes in the islands of the sea. (10) What is an earthquake? In what ways may it be produced? Tell the effects of some great earthquakes upon man. (11) Why do earthquake shocks usually precede a volcanic eruption? (12) How does the distribution of regions that suffer earthquake shocks compare with the distribution of volcanoes over the earth? (13) What is the difference between a terminal moraine and a ground moraine? (14) In what states should you expect to find glacial lakes? (15) Why are so many fences on New England farms made of small round stones? (16) Explain the presence of several ledges in Bronx Park, smoothed over but bearing long deep scratches. (17) What differences might we note if the ice sheet had not extended beyond the St. Lawrence and the Great Lakes? (18) To what parts of the world may tourists go to view glaciers? (19) Explain the presence of icebergs off Newfoundland. What effect have they on navigation? (20) Why do icebergs always float away from the glaciers?

EXERCISES. — (1) Make a diagram of a volcano, showing its various parts. (2) Write a paragraph explaining the cause of the eruption of mount Pelée. (3) Make diagrams showing a young and an extinct volcano. (4) Write a paragraph comparing the life history of a river with that of a glacier. (5) Make a diagram of a glacier from *Figure 98* naming the various parts. (6) On a map of the United States indicate the southern limit of the ice sheet. (7) Write a paragraph accounting for the deep valleys and rapid rivers of New England and the broad valleys and slow rivers of our southern states. (8) Make diagram of Niagara Falls showing the ledge of hard rock. Explain the formation of these falls. Why are they gradually moving back?

CHAPTER IX

THE GREAT WIND SYSTEMS

The Circulation of Air in a Room. — We have often sat near a stove or radiator when it was giving off heat and noticed the heat waves rising from the hot iron. In the country, lying on the grass under a tree at midday, we have seen air currents rising from the hot earth. The radiator of an automobile or the hot boiler of a locomotive has proved to us that when air near a hot body becomes heated, it rises from that hot body.

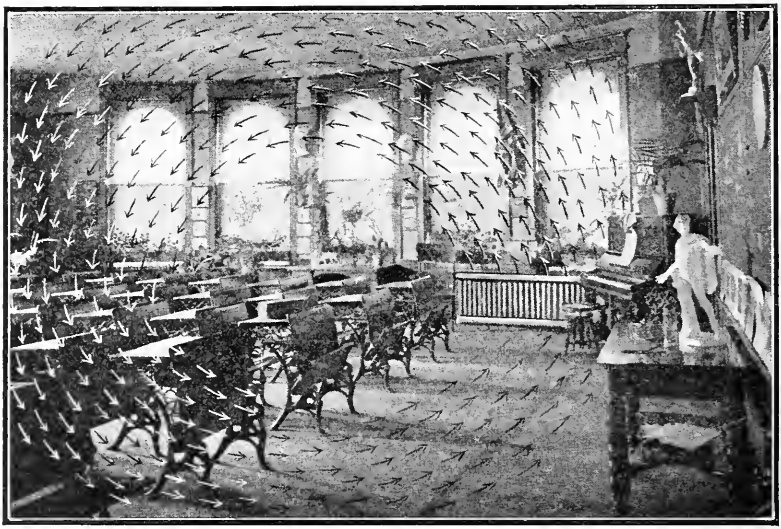

Fig. 103. The arrows show the circulation of air as produced in the room by the radiator.

In *Figure 103* is depicted the movement of the air in a classroom due to this fact. As the heated air leaves the radiators, it rises because it has expanded in heating and is therefore lighter than the

surrounding air. The cooler air along the floor hurries in to fill the empty space and in doing so it crowds up more of the heated air. Meanwhile the heated air continues to rise until it has given off its excess heat or till it has ascended to the ceiling. Then, becoming cooler, denser, and heavier, it settles again and gradually finds its way to the floor, to move again toward the radiators and again fill the space left by the warm air that has just risen from the radiators.

As soon as air is **heated,** then, it **expands,** therefore becoming lighter, and **rising.** When air **cools,** it **contracts,** grows heavier and **descends.** Firemen know this fact when, trapped in a room by fire, they lie down, with nose close to the floor in order to get cool air into the lungs.

The Cause of Winds. — The vast sea of air lying around the earth is acted upon in a manner similar to the air in this room. First, the earth in the torrid zone is heated by the direct rays of the sun until the land there acts like a huge radiator and causes all the air lying above it to expand and rise. Then the cooler air lying to the north and south of the torrid zone, only moderately heated by the slanting rays of the sun, flows in, as *Figure 104* shows, and pushes the warm air toward the equator and then upward. In this way winds are caused on the earth's surface, for wind is merely air moving horizontally.

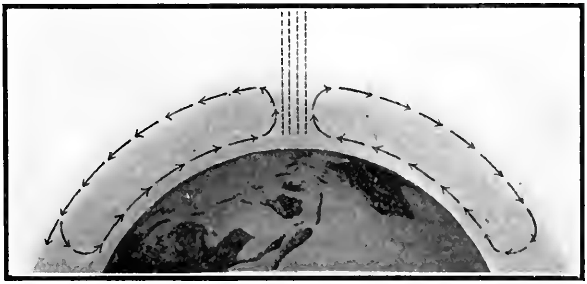

FIG. 104. Over the warm regions of the earth the air rises and moves toward the cooler regions.

In *Figure 105* we can see what becomes of this air thus driven from the equator. We find that it rises several thousand feet and then turns to flow toward the cold polar regions. To replace it cool surface currents flow in from the cooler zones. This cold air stays near the earth's surface. As these warm upper currents are continually cooling while they travel toward the poles, they will finally descend to the surface and rejoin the cold currents on their way toward

the equator. Again, the cold currents, as they travel southward along the surface, will have their temperature increased and will have to rise. You will also notice that near latitude 30° a part of the outflowing currents which descend to the surface joins the cold currents on their way to the equator, while the remainder continues toward the polar regions to take the place there of the cold air moving toward the equator. The reason for this is that much more air is required to replace the rapidly rising currents of the equatorial region than is required near the poles, where the movement of the currents is much slower. As a result of this, a point will be reached where the polar-bound currents will fall and the equator-bound currents will rise, and no air will blow horizontally.

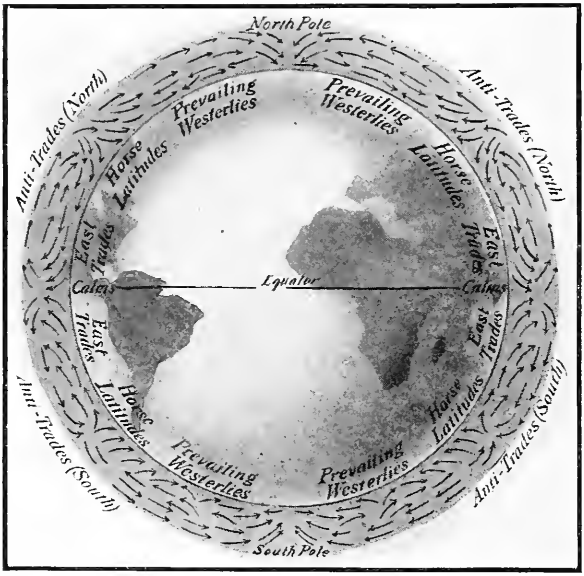

FIG. 105. The wind systems of the world.

The Trade Winds. — The air that we found flowing steadily toward the torrid zone causes very regular winds called **trade winds.** They begin in the north and south temperate zones and blow toward the equator. Therefore they are called the **north trades** and **south trades.** When the trades become heated they rise to the upper atmosphere and flow back again. They are then called **anti-trades** (opposite trades) or return trades (*Figure 105*). As the air approaches the equator, it becomes warmer, and we have learned that warm air is better able to absorb moisture. For this reason, the trade-wind area on the ocean is noted as a clear-weather belt because these winds ab-

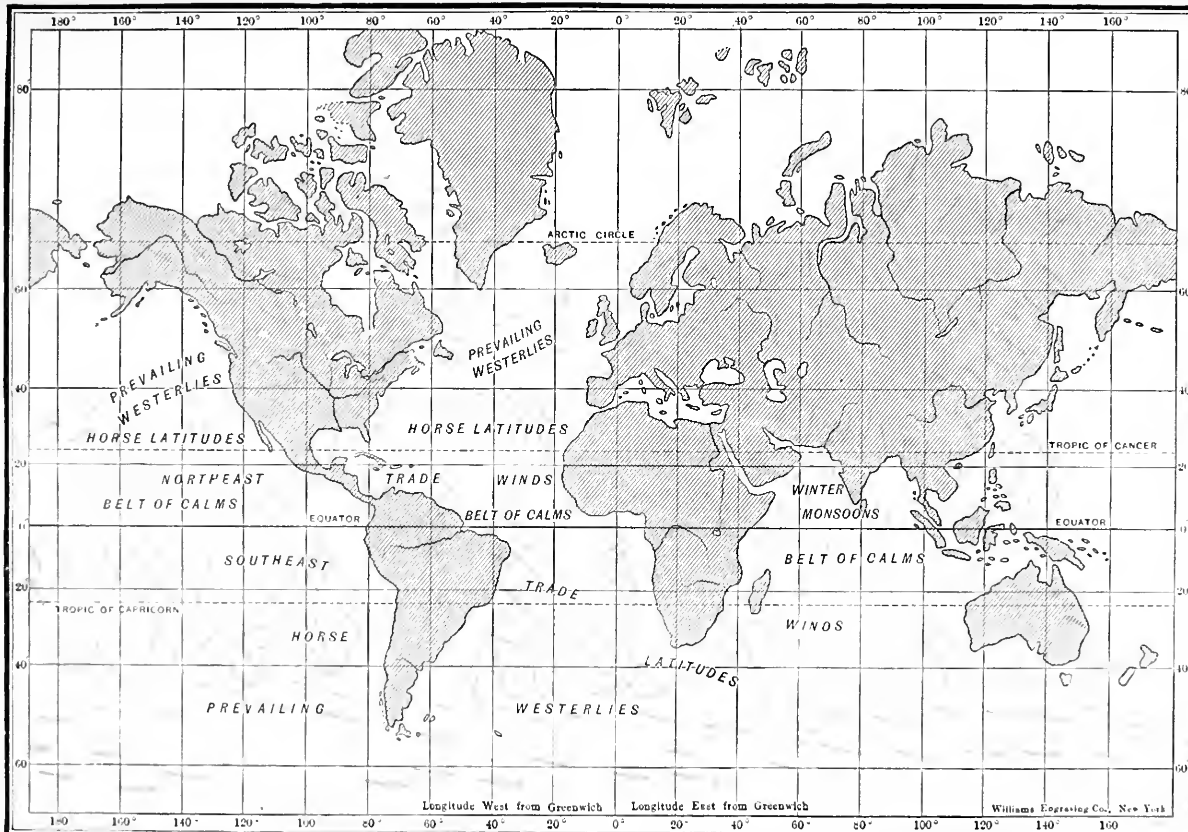

Fig. 106. The principal wind belts of the world.

sorb all the moisture. The few clouds are high and rapid in motion, the sky and sea are a clear blue, and the air is healthful.

The Equatorial Belt of Calms. — When the warm air is rising at the equator and the cold air falling, no air current is blowing horizontally, so that there is little or no wind at that part of the earth. This region, extending about one hundred miles north and south of the equator, is called the **belt of calms.** To-day a steamer chugs along as readily through calms as through trades; but years ago, when sailing vessels carried the greater part of our commerce, captains were often forced to wait for weeks in the calms to get enough wind to carry them across to the south trades or vice-versa.

Effects of the Earth's Rotation. — So far we have assumed that the trades and anti-trades blow directly north and south from the equator toward the poles. If we consult the wind map (*Figure 107*) we see that the wind arrows do not point in a north-and-south direction. This is explained by the fact that the earth does not stand still, but, as we have found out, the earth is rotating on its axis from west to east. At the equator the speed of this movement is about one thousand miles an hour. It grows less as we near the poles. Gravity tries to hold the atmosphere to the earth during the rotation and tries to carry it along at the earth's speed. But the air is the lightest part of the planet; and when the earth rotates to the east, the air and all the winds with it tend to lag behind, and seem to have a motion in the opposite direction.

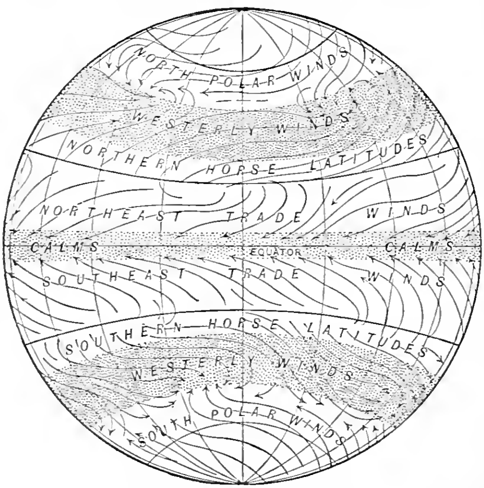

FIG. 107. The wind belts on the rotating earth.

The effect of this is, toward the equator where the rotary motion is swiftest, to turn trade winds from their straight course. In the

northern hemisphere, the winds are deflected to the *right* so that they blow from the northeast instead of from the north. In the southern hemisphere, the winds are deflected toward the *left* so that they blow from the southeast instead of from the south.

Imagine an axis driven through the sphere in *Figure 107*, and the globe rotated rapidly from west to east. If you should attempt to trace with chalk a meridian from the equator to the poles, you would produce a series of lines curving to the east as shown in the diagram. If you should try to trace a meridian from pole to equator, your attempts would be lines curving to the west. This aids in showing us the effects of our planet's rotation upon the wind systems.

For the same reason, the anti-trades are turned toward the *right* in the northern hemisphere, where they blow from the southwest, and toward the *left* in the southern hemisphere, where they blow from the northwest. The movement of very high clouds and of ash erupted from volcanoes proves this fact. On high peaks which rise above the level of the trade winds as in the Hawaiian islands, the anti-trades may be felt.

The Horse Latitudes. — We have before noted a region about latitude 30° where, both north and south of the equator, much of the air of the anti-trades settles to the earth again, as *Figure 105* shows. Just as in the equatorial belt of calms, so here there can be no steady horizontal motion of air, because the movement is downward. This is a belt of relative calm with irregular, unsteady winds. This region formerly was also very trying to navigators, and many vessels in voyages from New England to the West Indies were delayed by calms. In the early days many of these sailing vessels carrying horses were forced to throw them overboard when the fresh water gave out, and this fact gave this belt of calms the name of "horse latitudes."

The Prevailing Westerlies. — As we come to the region north and south of these horse latitudes, we find that much of the air of the anti-trade winds settling down to the surface flows on toward the poles, blowing in an easterly direction. This, we found, was due to the rotation of the earth. Since the wind blows toward the east, it comes from the west and is therefore called a **westerly wind.** As a result of these currents, almost all the United States and Canada, northern and central Europe, the southern part of South America and the

Southern ocean south of the 40° parallel, receive these westerly winds. In this way the westerlies blow throughout the greater part of the north and south temperate belts and affect the regions occupied by the most important nations of the world.

Frequent storms in these latitudes interrupt these winds and cause them to blow from any direction; but the most constant (prevailing) point from which they blow in the northern hemisphere is the west. In the southern hemisphere, where they have great expanses of ocean to blow across, and few land elevations to check them, these winds are stronger and steadier. For this reason they are here known as the Brave West winds. The westerlies, or the Roaring Forties, were of the greatest importance to sailors in the days of the old clipper ships, but with the coming of steam vessels their influence on navigation has been lessened.

Polar Winds. — Little is known about the polar winds. They originate in the polar regions and blow from the northeast in the northern hemisphere and from the southeast in the southern hemisphere. They were generally believed to be stormy but the reports of explorers seem to contradict this notion.

The Wind Belts. — *Figure 105* shows us how these belts of winds extend around the earth. Notice how the system we have described is repeated around the earth's circumference. Notice the alternation of equatorial calms, trades, calms, westerlies and polar calms. In *Figure 106* contrast the regularity of the northern and southern westerlies. Water is always more evenly heated by the sun than the land is. One region on land may become much warmer than another on the other side of a mountain range. In the warm area the heated air will rise and winds will blow to fill up the empty space in the air. This will change the direction of regular winds on land, while on the ocean nothing like this will occur. Mountain ranges and high plateaus also turn winds from their course.

Effects of the Earth's Revolution. — We have seen that in June the rays of the sun are vertical at the tropic of Cancer. This means that not the equator but a belt lying a little north of the equator will receive the greatest amount of heat. The warm air will rise and the belt of calms will be at that region. So, in our northern summer,

the calms shift to a belt about 10° north latitude. In December the rays are vertical at the tropic of Capricorn and the hottest region moves back to a position south of the equator. Since the belt of calms moves in this way, all the wind belts of the earth are affected, and twice each year we get this slow shift of the winds, northward in summer, to the south in winter.

Classification of Winds. — The trades and anti-trades are called **constant winds;** while the westerlies, which frequently change their direction, are called **variable winds.** Winds always blow toward a heated area. During the day you have noticed at the seashore strong **sea breezes;** when the sun sets there is a calm and later the direction shifts and we have a **land breeze** at night. **Monsoons** are an exchange of winds between land and ocean. They are best observed in southern Asia. From May to October the cool air from the water rushes northward upon the heated land to strike the Himalaya mountains. During the remainder of the year the land becomes colder than the ocean, and the monsoon wind blows from north to south. These monsoons (" season ") and the land and sea breezes are called **periodical winds,** because they change their direction at the ends of certain periods. **Irregular winds,** caused by many other conditions, are very numerous; among them are the winds of thunderstorms and tornadoes, and volcanic winds, desert whirlwinds or sand storms, cyclone winds, and waterfall breezes.

Winds are of the greatest importance to the life of plants, animals, and men because they transfer great masses of air from one part of the earth to another. They carry the conditions of heat and moisture which exist in the regions from which they come to the regions over which they will blow, and as they go on they themselves gradually acquire new conditions. Winds blowing over warm waters become laden with water vapor, winds from a large land mass are dry and may be the cause of deserts in lands to which they blow. Winds moving from a warmer to a colder region bring warm, damp weather, and winds blowing from a colder to a warmer region bring cool, dry weather. Most changes of weather are due, as we shall find, to changes in the direction of the wind. Some winds are agreeable and favorable to life, while some bring suffering, destruction and death.

QUESTIONS. — (1) Why do we open the windows at top and bottom to ventilate a room? (2) Explain the circulation of air around a lighted lamp. (3) What is wind and how is it produced? (4) Name the wind belts from the equator to the poles. How is each system produced? (5) In what ways do winds aid man in making the earth his home? (6) Describe the effects of irregular wind currents on balloons and aeroplanes. (7) What effects would be produced on our wind systems should the earth stop rotating? (8) Suppose the axis of the earth had no inclination, how would our wind systems vary? (9) Tell whether the westerlies are best developed on land or water. (10) Why are winds so regular on the ocean? (11) Explain the causes of trade winds, monsoons, land breezes, and sea breezes. (12) What are the possible effects of desert whirlwinds on erosion? (13) Why were the westerlies called the Roaring Forties?

EXERCISES. — (1) Diagram the circulation of air around a candle flame. (2) Make a map of the Atlantic, showing the position of trade-wind belts, westerlies, and the belt of calms. (3) Make a sketch of the sails of a small boat when moving under a stiff breeze, and when caught in a calm. (4) Make diagrams showing the direction of land breezes and sea breezes. Tell the effects of these changes on sail-boats. (5) Write a paragraph on the effects of the motions of the earth on the wind systems. (6) Make a list of the great countries blown over by the westerlies. (7) Make outline maps of North America and South America. Show by arrows the direction of the trade winds. (8) Change the wind belts in *Figure 107* on your own diagrams so as to show their positions in the northern summer.

CHAPTER X

THE RAINFALL OF THE EARTH

Rain and its Causes. — We have seen how warm air is able by evaporation to absorb a quantity of moisture and to hold it for a time. This moisture may be partly condensed when the air cools into tiny particles of water and become fog. Fog particles sometimes become so large and heavy that they can no longer float, and fall as rain drops. **Rain,** then, is a result of the continued condensation of vapor — the union of fog particles, driven together by air currents; or the union of particles as they fall through the cloud. The chilling may also take place either through the rise of the air into higher and colder levels, or through its contact with a colder surface like a mountain top, or from its meeting a current of colder air. The rain of the world falls either where moist winds blow from the water upon the land, from cumulus clouds, or from cyclonic storms. Some of the heaviest rainfalls take place on mountains near the sea.

A gallon of water weighs ten pounds, and if spread out in a layer one inch thick will cover an area of two square feet. An inch of rainfall gives one hundred tons of water to the acre, or sixty thousand tons to the square mile, yet in the Khasia hills in Bengal, India, the rainfall exceeds six hundred inches yearly, the greatest in the world. On the other hand less than two inches has fallen in some years in the Mohave desert in California. Less than ten inches in any region means a desert or tundra. At least twenty inches are necessary for forests and for agriculture without irrigation. The lands most favorable for human occupation have from twenty to sixty or eighty inches a year.

Rain and the Winds. — The earth's atmosphere is the great carrier of water from ocean to land. The winds supply the motive power to transport this moisture until it drops again as dew, fog, cloud, rain, hail, or snow. Nature permits nothing to be lost or wasted.

The sun heats the ocean, evaporation takes place, and the warm, moist air rises. The winds blow the clouds over the land where they are cooled, and the moisture condenses and falls. Then it flows through river channels back into the sea again.

In this way ocean winds cause rain on mountain slopes and plateaus. The air, being forced to rise in order to pass the elevations, expands and cools in the upper regions, and rain generally follows. On the other hand when winds descend, the air, being pressed down by the weight of the atmosphere above it, is compressed and grows warmer. Instead of giving up its moisture it is now able to hold a great deal more, so that it seems dry and clear. This descending air evaporates water and dries up clouds. Rising air, then, expands and cools and brings rain; descending air becomes warmer and brings dry weather.

The Great Rain Belts; at the Equator. — Here in the belt of calms the warm, moisture-filled air of the northeast and the southeast trades is continually rising and cooling. In *Figure 108*, note that right around the earth heavy rains fall every day in this belt. Rainfall here is the heaviest in the world. The sky is always clear in the morning, but as the rays warm the air it rises, filled with moisture. So much damp air mounts upward that heavy clouds are formed, and these break in heavy rain showers. This lasts all day until the sun sets; then the air cools and ceases to rise, the clouds disappear, and the stars shine from a clear sky

In the Trades. — We say that when winds blow over mountains, the air is raised and condensed so that rainfall results. The southeast trades drive moisture-laden winds over Brazil, Madagascar, and eastern Australia, and these winds condense to produce heavy rainfall in these regions (*Figure 108*). In South America you notice that the western slope of the Andes is dry because these trade winds have given up all their moisture on the eastern side. As a result a part of Peru is almost a desert. By referring to the physical maps of Australia and Madagascar, decide whether this condition is also the case on these islands. The northeast trade winds, gathering their moisture from the ocean, bring heavy rains. Consult the wind map (*Figure 106*) and note their effect on eastern Asia, the islands northwest of Australia, and northern South America.

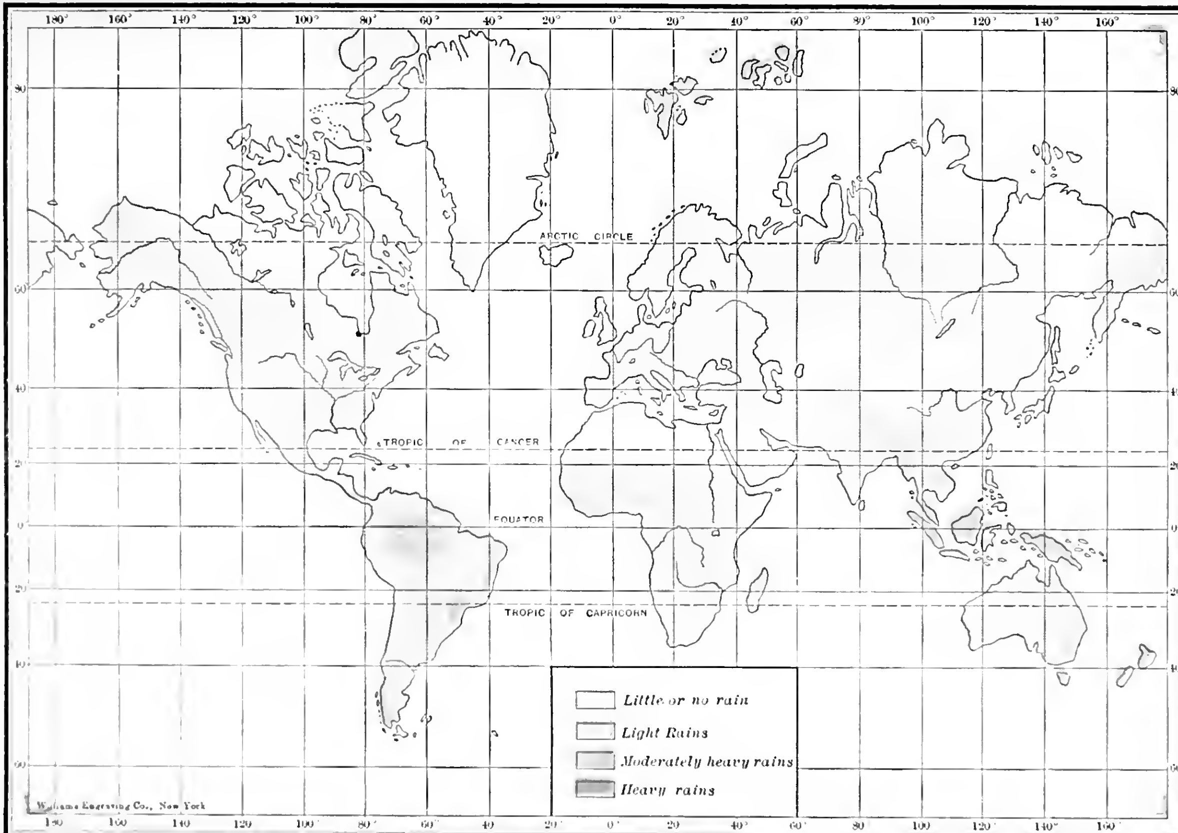

FIG. 108. A map of the world showing its rainfall.

When a wind blows from a cooler to a warmer region, far from being forced to give up its moisture by condensation, it is able to evaporate even more moisture and become a drying wind. This is the case with the northeast trades that blow over northern Africa and western Asia. In the first place they have been blowing over land instead of over water before reaching these regions and hence can have very little moisture; and secondly, since they are becoming warmer they take up whatever moisture there is. The Sahara desert is a result of this.

The Prevailing Westerlies. — These winds are good rain carriers. Blowing across the Pacific, they cause abundant rainfall on western North America and produce the same effect on northwestern Europe. In South America, Chile on the western side has a heavy rainfall for the same reason that Brazil gets it on the eastern side farther north. Here the westerlies carry over moisture from the Pacific. It will be noticed that in the belts where the winds blow upon the land the rainfall is heavy; while in those places where they blow over the land, it is slight. Here the winds blow upon the steeply rising land of the Andes. The vapor is condensed by the rapid drop in temperature, and the westerlies are drained of their moisture. When they blow down on the opposite side, they are dry winds, producing deserts.

These westerlies pass to the south of Africa, but reach New Zealand, the southwest tip of Australia, and the island of Tasmania. *Figure 108* shows that these regions get ample rainfall.

The Horse Latitudes. — At the horse latitudes, air is descending only and we must expect very little rain. Northern Mexico and southern California, southern Spain, Italy, Greece, and the northern part of Africa feel the effect of the rainless wind. The middle western part of South America, southwestern Africa, and western Australia are likewise afforded little rain.

Movements of the Rain Belts. — We saw that the effect of the earth's revolution on the winds was to shift the wind belts north in summer and south in winter. This shifting of wind belts causes the rain belts to move also. *Figure 106* shows us that many places like Central America, Venezuela, and middle Africa are in the belt of calms during the summer months and will therefore receive heavy

daily rainfall. But during the winter months, the trade winds will sweep them. In this way these places have two seasons: a **wet season** when the region is in the belt of calms, and a **dry season** when the trade winds blow.

Storms; Cyclones. — The prevailing westerlies are also called the **stormy westerlies** because the regions over which they blow are subject to frequent storms. A storm is always any condition of cloudiness accompanied by rain. Almost all of the United States, western Europe, the southern part of South America, and the part of Australia and the islands nearby (*Figure 108*) reached by the westerlies have frequent storms. They are caused by heavier air flowing rapidly into a region of light rising air. These incoming air currents take on a spiral motion which grows swifter and swifter as they approach the center. The inflowing air drives the warm damp air upward where it cools and condenses. Clouds and rain follow. The stormy area does not remain in one place but whirls swiftly onward across a continent, drawing the air in toward it for hundreds of miles. In the United States they always start in the northwest (see *Figure 129*), move rapidly eastward, and generally pass over the Great Lakes and outward to the Atlantic down the St. Lawrence valley. Such a storm is called a **cyclone** (whirl round).

Tornadoes. — Sometimes on very warm days the air lying near the surface of the earth gets very hot and full of moisture, while the air above the earth is heavy and cold. After a little the hot air rises suddenly in the form of a huge funnel, and the heavy air drops down, producing sudden and heavy rainfall. It also develops a terrific whirlwind when the surrounding air rushes into the path of the storm. These storms often occur in the central and eastern United States in the spring of the year. They are called **tornadoes**, and many of

Fig. 109. Photograph of a distant tornado.

them (see *Figure 111*) have caused an enormous amount of damage, since the wind sometimes reaches a velocity of 200 miles an hour, and nothing movable can resist it.

A **waterspout** is formed by a tornado at sea drawing up a column of water into its funnel instead of taking up air and cloud. The larger part of the water, however, is probably formed by the condensation of the water vapor in the air, and not by the uplift of water from the sea.

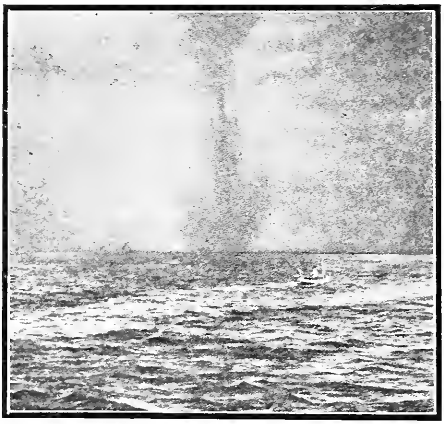

FIG. 110. A waterspout at sea.

Thunderstorms are seldom cyclonic, but result from the rapid rising of currents of warm air until heavy cumulus clouds are formed at the top. They bring violent gusts of wind and a downpour of rain, which leave the air cool, clear, and bracing.

Hurricanes. — These are destructive cyclonic storms that visit the West Indies in late summer and autumn, arriving from the southeast. They begin in the equatorial calms and increase in expanse until they reach a diameter of 100 to 200 miles. On land they destroy almost everything — forests, crops, buildings, and people. On the sea they are very dangerous to shipping and pile up the water until it sweeps over the coast lands, flooding fields and towns. When they approach the United States, they usually turn to the northeast and die away in the north Atlantic. In September, 1900, the city of Galveston, Texas, was destroyed by a hurricane which passed westward. Six thousand lives were lost in this city and the damage to property was estimated at more than $30,000,000. Similar storms occur in the Indian ocean both north and south of the equator. In these regions they are called **typhoons.**

Other Causes of Rainfall. — Cyclonic storms pass across Europe in the same direction as they pass over our country, changing the weather very markedly in a few hours. In the corresponding lati-

tudes of the southern hemisphere also they change temperature, wind, and rain.

In discussing winds we noted land breezes and sea breezes. You will be able to see now that sea breezes in summer often bring showers of rain, when they come in laden with moisture to strike some elevated and therefore cool land areas, or to meet some currents of cold air.

FIG. 111. The effects of a tornado in the middle west.

In studying the monsoons of India, we saw how during six months the cool ocean air for hundreds of miles rushes in on the land, and how during the winter months the heavy air over the cold land settles down as a drying air, and presses outward beneath the warmer air which is rising over the ocean. India, then, in the summer has the moisture-laden ocean winds carrying the heated air of the continent up the steep slopes of the Himalayas and giving her a rainy season. In winter she has her dry season, since the land cools more rapidly than the ocean and drives dry air out from the continent. In one month of her rainy season, India receives three times as much rain as our eastern United States; while during her winter monsoons vegetation withers as in a desert.

QUESTIONS AND EXERCISES. — (1) What is rain and how is it caused? (2) What is the relation of winds to rain? (3) Why is rain abundant in the belt of calms? (4) What rainfall conditions would you note in spending a day on the Amazon?

(5) Explain what is meant by a rainfall of 30 inches. What amount of rainfall is most favorable to man? (6) Why is rainfall greatest on the eastern slope of mountains in the trade-wind belt and on the western slope in the westerlies? (7) In what directions do cyclonic storms move and what is their extent? (8) Why is man interested in tornadoes, hurricanes, and thunderstorms? (9) Account for the formation of cyclones. (10) Explain why the trade-wind belt contains so many deserts. (11) Make a list of the countries in some one continent that lie in the westerlies and which have a heavy rainfall. List those having a light rainfall. (12) Account for the following rainy regions: Amazon valley, northern India, rainy season in Cuba, central Africa, Philippine islands, southern Chile, the Canal zone. (13) Account for the aridity of central China, south Africa, dry season of India, Sahara desert, Argentine pampas. (14) Contrast the rainfall of Labrador and Norway. (15) Explain the rainfall of all countries along the 60° parallel of north latitude; the 20° parallel of south latitude; the 120° meridian of east longitude; the 20° meridian of east longitude. (16) Why are the interiors of North America and central Eurasia similar as regards rainfall? (17) Why do not the monsoons from the Indian and Pacific oceans bring rain to central Asia? (18) Explain the causes of the Arabian and the Persian deserts. (19) Indicate the regular rain belts on an outline map of the western hemisphere. Explain the shifting of these belts and its effects. (20) What effects do thunderstorms produce in a large city?

Rainfall of the United States. — In our own country we can observe the rainfall conditions of the whole world except those of the tropical regions. We have seen the effect of the westerlies bringing rain to the western slopes, these winds then losing their moisture in passing over the highlands and leaving the middle west with little rainfall. Here the country is in an arid and almost a desert condition.

You will observe that the western part is divided into a number of north-and-south belts of varying rainfall. Owing to the trend of the highlands, the moisture is greatest near the Pacific coast, on the windward side of the Coast range, and the still higher Sierras and Cascades. Only on the tops of the Wasatch and other high Basin mountains does a little rain fall in this otherwise dry region. Again, farther east on the still higher and colder Rockies, some more of the moisture of the westerlies is condensed. But as we have seen, the winds continuing eastward fall on the eastern side of the Rockies and here again are drying because they are becoming warmer. Thus they render the Great Plains almost arid.

The great storm belt (see *Figure 129*) however aids us in understanding why our central and southern states also are not dry and desert. Abundant rains fall in this section due to the very irregular winds and storms. Practically all the rain falling east of the Rocky

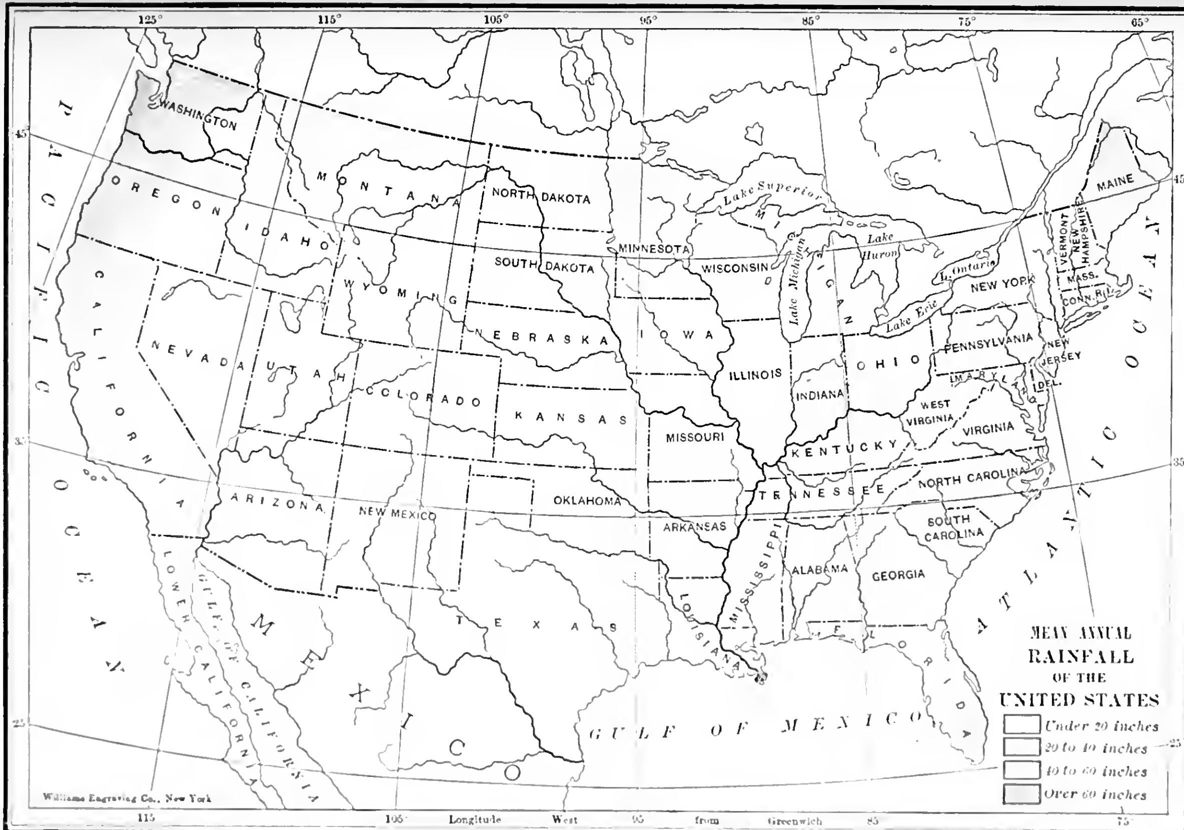
MEAN ANNUAL
RAINFALL
OF THE
UNITED STATES
Under 20 inches
20 to 40 inches
40 to 60 inches
Over 60 inches
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
MARYLAND
DEL.
PENNSYLVANIA
NEW JERSEY
NEW YORK
VERMONT
NEW HAMPSHIRE
MAINE
MASS.
CONN.
R.I.
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
L. Ontario
LOWER CALIFORNIA
GULF OF CALIFORNIA
Longitude West from Greenwich
Williams Engraving Co., New York

FIG. 112.

mountains comes as a result of these cyclonic storms tearing across the continent. Their moisture is supplied by the gulf of Mexico and the Atlantic ocean, and their extent is often so great that one storm may be causing rain in Louisiana and Ohio at the same time.

The rainfall which *Figure 112* shows for the Texas coast is the result of the inblowing trades of the summer. Florida's rain depends upon the nearness of the warm ocean waters. Most of the winds in the east are from the land, and of course the rainfall here is less than on the western coast. Since we pass from warm to cooler areas in going from Florida to Maine, the rainfall decreases regularly. On the western coast, since the ocean winds blow against mountains, the greatest rainfall is in the north and the least in the south.

Throughout the greater part of the western half of the country you notice that the rainfall is very slight, because there are no great water bodies to supply the winds with moisture. The same conditions prevail in central Eurasia. Even in the states just west of the Mississippi valley, you notice that the rainfall is light because the winds are dry. Whatever winds reach this part from the gulf of Mexico have lost their moisture on the way.

REVIEW OF UNITED STATES RAINFALL. — (1) What is the result of the absence of lofty mountains in the southern United States? (2) Explain why the rainfall of Washington varies from under ten inches to over sixty inches. (3) Explain the presence of deserts in Nevada and Arizona. (4) Which winds are dry in the northeastern United States and which carry vapor? Why? (5) Explain the rainfall in all states crossed by the 35° parallel. (6) How does New York City get its rainfall? (7) What results might be noticed if the western highlands ran east and west? (8) Can you trace any effects of the rainfall differences on the products of the five groups of states? (9) Compare the rainfall of Florida with that of Maine. Account for the difference. (10) In what directions do cyclonic storms move and what is their extent? How do these affect the rainfall of the United States?

CHAPTER XI

THE CAUSES AND EFFECTS OF OCEAN MOVEMENTS

Waves. — The great expanse of water which forms seven tenths of the earth's surface is never at rest. Just as you can produce small waves by blowing on a saucer of water, so the winds blowing over the surface of the ocean produce waves by their friction. The height and velocity of these depend on the force of the wind and the depth of the basin in which they occur. In the movement, the water particles travel forward very little, but the wave form travels through the water great distances. If A B in *Figure 113* were a rope and you should shake it violently, you would produce a wave form passing along the rope, though the particles of the cord would move only up and down. Water in wave movements acts almost the same as these rope particles.

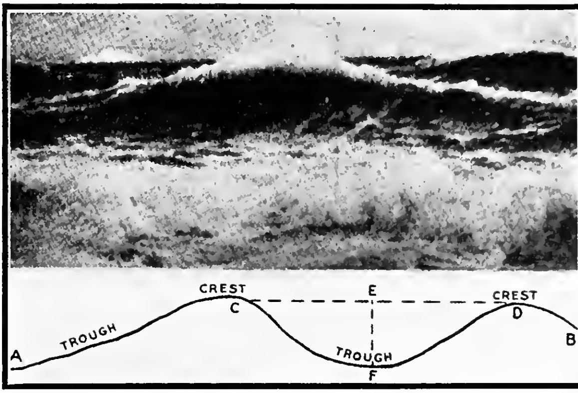

FIG. 113. A diagram of a wave form.

When a wave approaches shallow water at shore where there is not enough water to continue the form, the water advances and the wave increases in height and decreases in breadth until at last the top portion falls with a blow on the shore, causing breakers or **surf** as in *Figure 114*. The water which runs down the beach after it has been thrown up by the breakers, forms the dangerous **undertow** of our bathing beaches.

In the open sea, with a moderate wind, the height of ordinary waves is about six feet, while the distance between two successive wave-crests is about fifteen times their height. In storms, waves often rise over sixty feet in height and dash along at a speed of sixty miles an hour. The wind then mixes much air with the foam and spray of the crests and produces whitecaps (*Figure 113*).

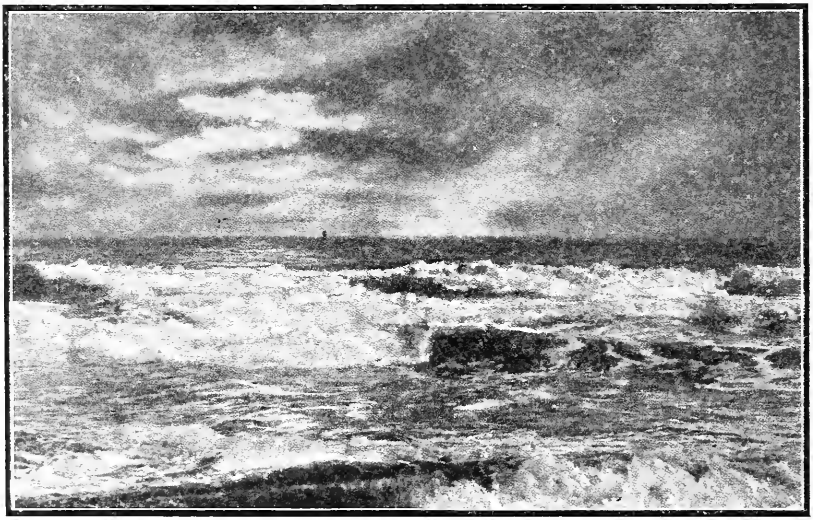

FIG. 114. The advance of waves on a beach, forming surf.

Effects of Waves. — Heavy waves, weighing many tons, often cause serious damage to ships at sea. Even great liners are often forced to change their course to avoid the danger of being capsized by them. They dash over the decks, tearing away heavy rails and ironwork, smashing lifeboats, and flooding saloons. Many smaller vessels, never heard from at sea, have been sunk by them. The carrying of oil for the purpose of stilling waves in violent gales is now common. The oil poured over the waves spreads in all directions, and the water is calmed because the oily surface offers less resistance to the wind.

In storms, waves do damage on shore also, wrecking pavilions, buildings, piers, as well as vessels anchored near-by. The ceaseless

pound of the surf forms our sand beaches by grinding up pebbles and shells. The wave action eats away cliffs and rocks, or cuts them into fantastic shapes. In this way, it may often change a coast line by cutting it away. Ships are unable to come close to land on such

FIG. 115. A pier built for the docking of vessels unable to approach a regular coast.

a coast, and it is necessary to extend great piers out into the water in order to provide facilities for the discharging of cargoes.

Tides. — The second principal movement of the ocean water is caused by the tides. Twice every day the surface rises and falls in a slow, mysterious movement, that has puzzled man for ages. The interval between high tides is about twelve hours and twenty-six minutes. For six hours the water crawls up the beaches or mounts higher and higher around the piles of docks and piers until it reaches the **high water mark**, and we have high tide. Then for six hours the water ebbs or slowly recedes to **low water level**, when we have low tide. These movements are called **flood tides** and **ebb tides**.

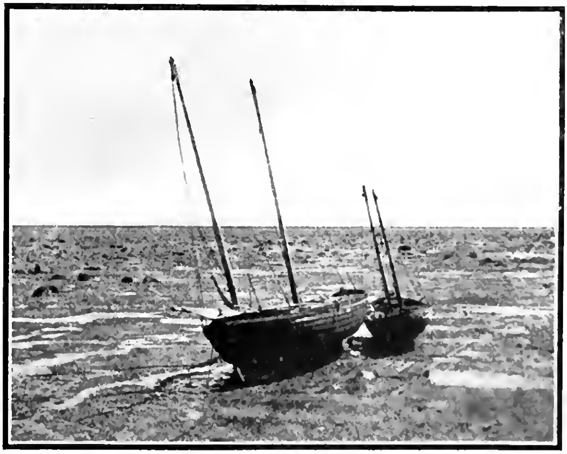

FIG. 116. A beach at low tide.

The Causes of Tides. — Hundreds of years ago, it was observed that the flood and ebb of the tides corresponded with the position and phases of the moon. We have seen that there is the force of gravitation always working between the earth and the moon. This force will tend to attract to the moon any light part of the earth, such as the hydrosphere. The solid land is able to resist the tendency to move, but the liquid sea yields to it. In this way some of the water of the earth is drawn up from the surface as shown at B (*Figure 117*). Since the center of the earth, upon which the moon's pull is always concentrated, is 4,000 miles nearer to the planet than the water on the earth at A, her force will be greater on the center of the earth than on this water at A. As a result, when the water at B is attracted, the whole globe is next attracted and is lifted up and away from the ocean water at A. These two attractions then cause the water to rise in two tides as shown, and to become lower at C and D.

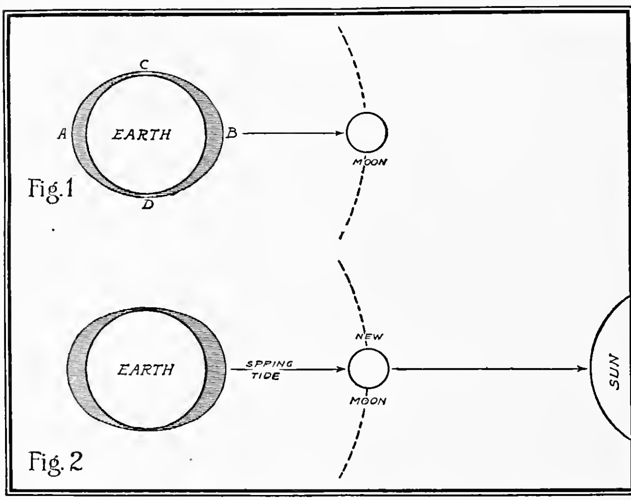

Fig. 117. 1. Flood and ebb tides as produced by the moon. 2. The formation of tides at the time of new moon.

Due to the earth's rotation, this mass of raised water, really stationary, seems to move around the earth every twenty-four hours from east to west. This diagram shows two flood tides on opposite parts of the earth and two ebb tides at right angles to them. In this way, each tide will last one quarter of the twenty-four hours, or six hours. The duration of the long, low tidal wave is then about twelve hours — six hours for the flood and six hours for the ebb.

Spring and Neap Tides. — In addition to the gravitational pull of the wave on the earth, there is also the attraction of the sun for this planet. This power is much greater than that of the moon, and a tidal wave is also produced on the earth by the sun. This wave is less than one half as high as the moon's, for although the sun's attraction is greater, the sun is so much farther away that its attraction is practically the same on the opposite sides of the earth. The mere 8,000 miles of the earth's diameter makes no appreciable difference.

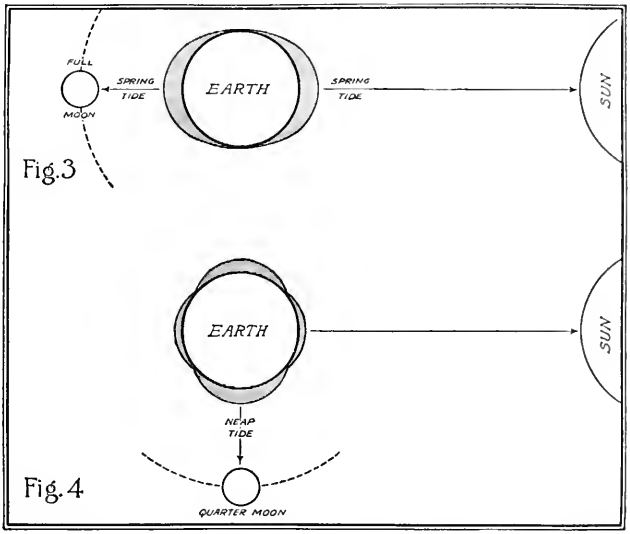

Fig. 118. 3. The formation of tides at the time of full moon. 4. The formation of tides at a time half way between new and full moon.

Review at this point the phases of the moon. In *Figure 117* (Fig. 2), at the time of new moon, we find both moon and sun uniting their force on one side of the earth in one straight line. A very high tide is produced which is called a **spring tide** because it seems to spring up. In Fig. 3 the moon has moved around in its orbit and is drawing on the earth along one line while the sun is pulling along another. The lunar, or moon tide, is therefore made much less and is called a **neap** (scanty) **tide.** In Fig. 3, at full moon, the sun's force again unites with the attraction of the moon, and again we have a very high spring tide. The moon makes its revolution in four weeks; and twice during this time we have spring tides at new and full moon, and twice neap tides at the first and third quarter.

Irregular coast lines, different depths of the ocean water, winds, channels, and harbor entrances all produce endless varieties of tides, so that each place at or near the ocean has its own conditions which affect the height and time of its tide. On the open sea, the change is between one and two feet, but when the tidal wave strikes the shores many variations occur. At New York the spring tide is 5.4 feet above low water mark; at Boston, 11.3 feet; at Savannah, 8 feet. At the bay of Fundy, a funnel-shaped inlet, the variation between low and high tide level is over 50 feet. The Atlantic tide, passing through the straits of Gibraltar into the broad Mediterranean, produces no effect on it.

Effect of Tides. — Out on the open ocean, tides are of no importance. Ships never feel them. But along shore, these currents

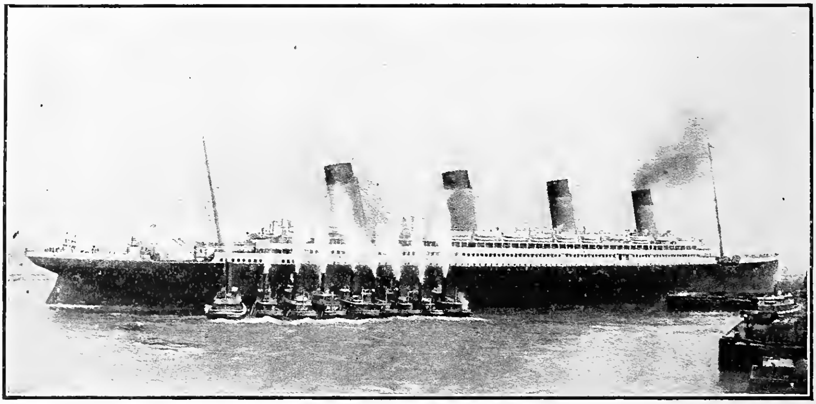

Fig. 119. An ebb tide preventing the docking of an ocean liner.

are of much importance. Where a channel is narrow and rocky, the incoming and outgoing tides change into swift and dangerous streams, as in Hell Gate in New York. These are called **tidal races.** Frequently they delay sailing vessels or drive them into dangerous positions. Tidal currents along a shore drift vessels out of their course and often wreck them.

When the tide enters the mouth of a river with a strong current, the water rises in a high mass which travels upstream very swiftly, often wrecking small ships and doing damage along the coast. This

rush of water is called a **tidal bore.** The flood tide then lasts only a moment, while the ebb tide follows for about twelve hours. The bore is seen at the bay of Fundy, at the mouth of the Severn in England, of the Amazon, and of the Seine.

Tides and waves constantly change the contour of coast lines by either carrying sediment from harbors and river mouths and depositing it along the coast, or by choking up harbor entrances by depositing sediment in them. This must be removed by the government at great cost. Sometimes they wear away the land at one place to build it up at another. They carry off sediment from the land and produce continental shelves like the banks of Newfoundland. Their action, rushing in and out of narrow estuaries, washing out the river sediment, is often sufficient to keep channels deep enough for large vessels. On the other hand, they frequently deposit the sediment outside a harbor, producing sand bars which are always a menace to navigation. Sewage disposal is always easier for cities near tidewater.

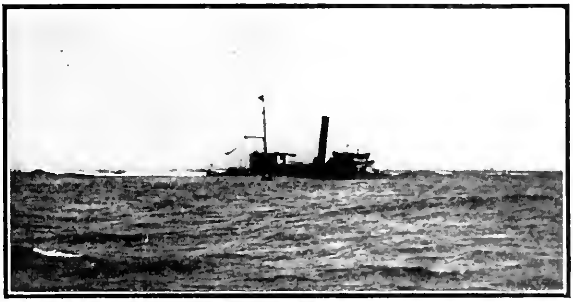

Fig. 120. A freighter wrecked on a hidden sand bar.

Fig. 121. The effects of a giant water wave accompanying a storm in the West Indies.

QUESTIONS. — (1) How does the wind, blowing over a corn field, make it resemble a water wave? (2) Does water move at all when a wave passes? Explain just how it moves. (3) How are breakers produced? What is their effect upon the shore? (4) Why is the undertow dangerous? (5) Describe some of the effects of waves on ships at sea. (6) Why is oil used in a storm? (7) What effects along shore are produced by waves? What are breakwaters? (8) In what other ways does man try to meet the effects of wave action? (9) Distinguish between flood and ebb tides. (10) What effect would be produced on tides if the earth stopped rotating? (11) What is the effect of the sun on tides? (12) Distinguish between neap tides and spring tides. (13) Tell about the effects of tides on coast lines, harbors, channels, vessels at sea and near land. (14) What is the difference between a tidal bore and a tidal race? (15) What difference would you note in *Figure 116* at high tide?

EXERCISES. — (1) Make a diagram of four wave forms. Name the parts, and with arrows show the movements of the water particles. (2) Make diagrams showing the difference between a wave at sea and one nearing a beach. (3) Explain the different reasons for building the pier shown in *Figure 115* and our piers along the Hudson. (4) Make diagrams of the earth, moon, and sun at neap and spring tides. (5) Make a list of all the coast formations in Europe which would tend to make tides irregular in time and height. (6) Write a paragraph explaining how spring tides and neap tides differ. (7) Make a list of the large tidal estuaries along the coasts of the United States. (8) Would a tide run farther up the Hudson or the Mississippi? Why?

Ocean Currents. — The third principal movement of the ocean water is produced by **currents.** These are practically rivers of warm or cold water flowing through the ocean as shown in *Figure 122.* They are caused by the steady winds blowing over the seas and producing not only waves but in addition a slow movement of great masses of water underneath the surface. Again, since the rotation of the earth affects the winds, it acts also as a cause of the flow of ocean currents. A current so slow as to be almost indistinct is called a **drift.**

The movements follow a very definite path. The currents in the northern oceans move from the east to the west along the equator, then to the north and again to the south, turning in the same direction as the hands of a clock. The direction of the southern currents is opposite to the direction of the hands of a clock. On *Figure 122* trace the effect of the trade winds and the westerlies upon these currents. You notice that it is only the continents that deflect them, so that winds, coast lines, and other currents determine their direction.

Warm and Cold Currents. — The water composing the ocean currents is warmed in equatorial regions and arrives in higher latitudes with a higher temperature than the sun is able to maintain at that latitude. It therefore is cooled by giving its excess of heat to

the water below and the air above, and arrives at the equator again, in the eastern part of the oceans, cooler than the equatorial air and water. The water and the air at the equator are slightly cooled when they give up some of their heat to the cooler current and when they aid the sun to warm it again for its westward flow. Thus all currents change the temperature of the region they pass through: if they come from a warmer region, they raise the temperature; if from a colder region, they lower it. One half of the heat received by the whole torrid zone is carried by ocean currents into colder regions.

Currents in the Atlantic. — North of the equator, we find in the Atlantic a **west wind drift** which, becoming the **north equatorial drift,** due to the effect of the trades, is carried westward toward South America. The continent deflects its course, and the rotation of the earth sends to the right that part of the current that is permitted to go northward. The rotation continues swinging this current to the right, so that instead of keeping along the American coast, it swings out into the Atlantic toward Europe. Continuing to turn, it breaks from the great **north Atlantic drift** and is again taken in hand by the northeast trades. These send it southward, until once more it becomes the north equatorial drift, having made a complete circuit.

Figure 122 shows us how the equatorial waters of the Atlantic, which are drifting westward, are divided at the eastern coast of South America. The smaller part is turned to the southwest to become the **south equatorial drift,** and the larger part to the northwest along the border of the continent.

The Gulf Stream. — *Figure 122* also shows how a part of the north equatorial drift, following the coast line of Central America, flows through the Caribbean sea into the gulf of Mexico. Here, the great **Gulf Stream** is born. This, from its supposed climatic influence, the best known of the great currents, derives its name from the gulf of Mexico, out of which it flows, between the coast of Florida on the one side and Cuba and the Bahama islands on the other. With a breadth of forty miles in its narrowest portion, it has a velocity at times of five miles an hour, pouring along like an immense torrent. At this speed it could flow around Manhattan island in about five hours. This current flows in a northeasterly direction along the American coast, gradually widening and diminishing in velocity, until

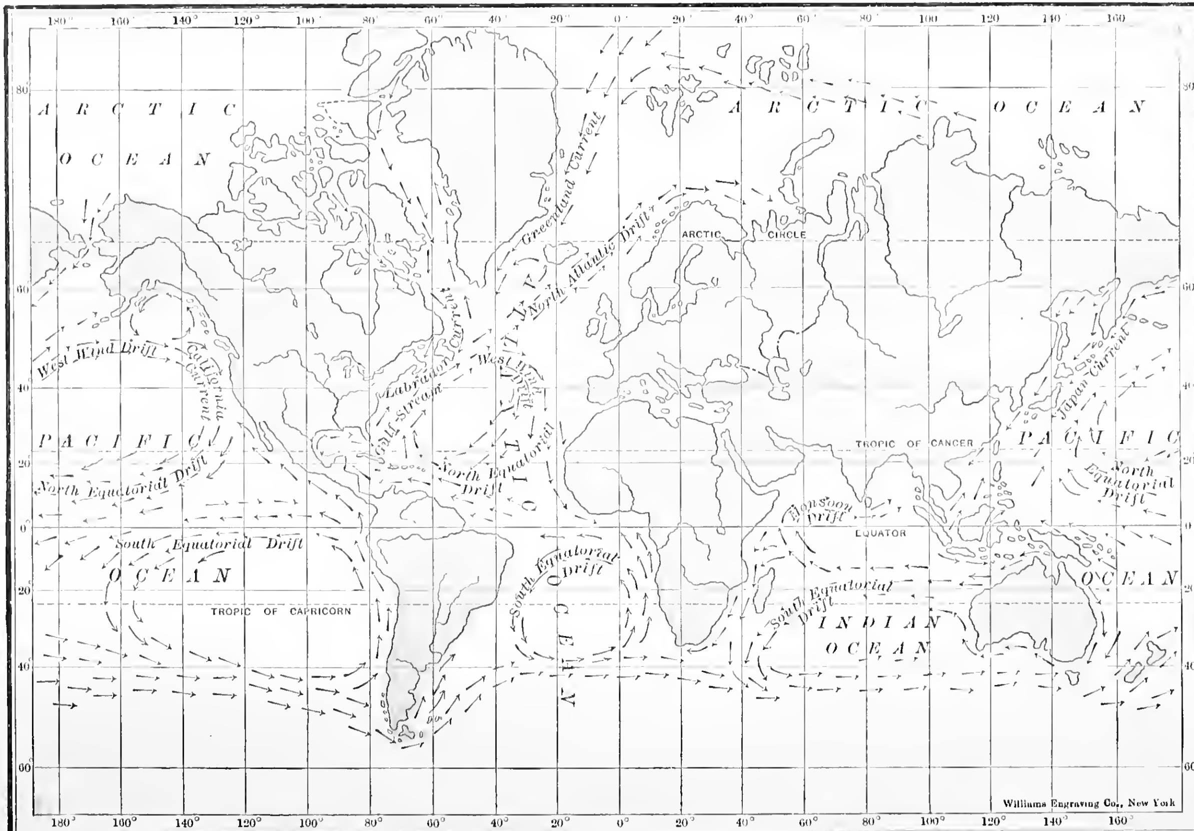

FIG. 122. A map of the world showing the ocean currents.

it reaches the banks of Newfoundland. Here, about 40° north latitude, it merges with the north Atlantic drift and approaches the coast of Europe. The waters of the stream, from 2,000 to 3,000 feet deep, now rise and spread out into a sheet of warm surface water, drifting at the rate of a mile or so a day into the Arctic ocean.

The waters of the Gulf Stream are of a deep indigo blue, with boundaries sharply defined against the light green of the seas through which it passes in its early course. It abounds with masses of seaweed, torn from the coral rocks when it has its power and velocity; and in its warm current may be seen myriads of fish. As it pours out of the gulf, it has a warmth of 84° F. in summer, being 4° higher than the temperature of the ocean at the equator. Owing to this warmth, a bank of fog, rising like a wall, often marks the edge of the stream as it meets colder water and air in its northward flow.

The Labrador Current. — We must remember that when any quantity of warm water is carried northward, the same amount of cold water must find its way to the warm regions. This is why the **Labrador current** flows southward to equalize the distribution of the earth's ocean waters. This frigid current comes from the polar regions, along the coast of North America as far south as the shores of Massachusetts. The rotation of the planet swings it to the right so that it hugs the coast line. We have seen the effect of these two currents, warm and cold, meeting off Nova Scotia and Newfoundland.

South of the equator in the Atlantic we find drifts similar to those of the northern waters, except that the earth's rotation swings them always to the left.

Currents in the Pacific. — Here we find the **west wind drift** shunted by North America to the south, becoming the **north equatorial drift,** due to the action of the trades. On approaching Asia, the drift separates, one part going to the north and one to the south. The rotation of the earth swings the north drift to the right, the southern part to the left. The west wind drift is taken in charge by the westerlies and driven eastward again, thus completing the system.

Near Japan, this northern current is known as the **Japan current,** since it takes up here a vast quantity of heated water and carries

it over to the western slope of Canada and the United States. In *Figure 122* observe the small frigid current that comes through Bering strait from the north, corresponding to the Labrador current.

The south Pacific drifts are again the same as those in the northern hemisphere, except that their direction is toward the left, due to the earth's rotation.

In the Indian ocean, south of the equator, the currents make a circuit, which is much like that in the Atlantic and Pacific oceans. We have seen how the monsoons of India change their direction twice a year. Very soon after the change in winds, the currents north of the equator here also change their course. In the summer, when the southwest monsoon flows, the currents move from west to east in the northern part of the ocean and from east to west in the southern part. In the winter, when the wind blows from the northeast, they reverse their course to correspond. This is an additional proof of the dependence of currents upon winds.

Around the south pole is the great drift of the Antarctic ocean moving constantly eastward, in the same direction as the southern part of the eddies of the several oceans.

Effects of Ocean Currents. — We can see now that the northwestern coasts of North America and Europe receive the heat and moisture of air heated by warm drifts of water from the southeast. The northeastern coasts of North America and Asia, however, are chilled by polar currents that flow southwest from the frigid zone.

The warm winds from the waters of the Japan current and the west wind drift of the Pacific cause the climate of Alaska to be far milder than that of Labrador in the same latitude. From California north the whole Pacific coast feels their influence in abundant rains, mild winters, and cool summers.

Ocean currents do not themselves warm or cool the land, but the air over a warm current is heated by the water and is then blown to the land. Without currents in the north Atlantic, the temperature over the ocean in the latitude of the British Isles and northward would be about 10° or more lower than now. Even without the Gulf Stream, the western coast of Europe, since it is in the belt of the ocean westerlies, would have a milder winter climate than the eastern coast of

North America in corresponding latitudes, but the drift of warm water into the north Atlantic makes the winter temperature of Europe north of latitude 50° considerably warmer than it would be otherwise. Hammerfest harbor in Norway, 76° north latitude, is troubled by ice about as much as New York harbor, latitude 40°.

The **shifting** of the course of the Gulf Stream, due to the action of strong winds, sometimes is mentioned as the cause of a mild winter in the United States. Winds may force the surface waters out of their usual course, but this shifting is always temporary and has little or no effect on our winters.

The chill winds of the Labrador current exert their barren effect on the northeastern part of our continent. The waters of the current, reaching the coast of the United States, send out cold winds that drive a chill into our seaboard states in winter but lend them a pleasantly cool climate in summer. In addition, this current brings with it much ice from the Arctic regions. Great icebergs, broken off from the Greenland glaciers, are kept frozen in the icy water until they come as far south as Nova Scotia. Here they drift into the paths followed by trans-Atlantic liners and prove a source of constant danger, especially in a fog.

The same effect as that of the Labrador current is produced off the northeastern coast of Asia. The chill winds from the icy waters make the Siberian coast barren and keep its harbors icebound in winter. Notice that Kamchatka and Scotland are in about the same latitude.

Work of Ocean Currents. — Currents have little effect on the ocean-bottom, and almost none on coasts, because in most places they touch neither. Where the water is shallow, however, a current may scour the bottom, as the Gulf Stream does between Florida and Cuba. Since ocean currents eat away but little land, they carry very little sediment. Warm currents carry multitudes of plants and animals, many of which are very small. These tiny creatures and their shells are scattered far and wide over the bottom of the ocean. The wreckage of ships and driftwood are often carried long distances by currents. In some places on the seashore driftwood supplied by the ocean currents is a valuable source of fuel. In the tropics seeds are often carried long distances in the same way.

QUESTIONS. — (1) Give the three principal movements of the ocean water. (2) Name four causes of ocean currents. (3) Name and locate five great ocean drifts. (4) Which, in your opinion, is the most important of the currents? Why? (5) Of what benefit are ocean currents in frigid and torrid zones? (6) What effects on climate might be observed if the Gulf Stream were caused to flow north through Davis strait? (7) On the treeless isles northeast of Japan tree trunks and tropical products are often found. Account for their presence there. (8) What difference in temperature should you expect to find at the eastern and western limits of the tropic of Capricorn in North America? (9) When we have a temperature of 40° at New York, it is no colder in the Aleutian islands. Account for this. (10) What difference would you expect to find in January in the commerce of Vladivostok and Victoria, B. C.? (11) What difference would we note if the Japan current ran northwest? (12) In January at latitude 4° north, longitude 0°, the temperature is the same as at latitude 35° south, longitude 25° east. Account for this difference. (13) Why do so many people spend their summers in Maine? (14) Account for the fact that the state of Washington has a pleasant climate, while Newfoundland is bleak.

EXERCISES. — (1) Make a chart of the ocean currents as they would move if no continents deflected them. (2) On an outline map of the north Atlantic, put in the currents, making warm currents red and cold ones blue. (3) Do this for the north Pacific. (4) Repeat exercise (2) for the south Atlantic. (5) Repeat for the south Pacific. (6) Make two maps of the Indian ocean showing by your arrows the currents in winter and summer monsoons. (7) Write a paragraph describing the work of currents in equalizing the temperature of the ocean water. (8) Repeat exercises (2) and (3), shading all the places on the oceans where fogs would be likely to form.

CHAPTER XII

THE WEATHER OF THE WORLD

Weather. — Our weather is the result of three things: (1) the temperature of the air, (2) the amount of moisture in the air, (3) the weight or downward pressure of the air. Differences in temperature produce the changes which perhaps we notice most, like winter and summer. Weather is fair, stormy, or cloudy as a result of variations in the amount of moisture in the air. Differences in downward pressure or weight of air cause the horizontal movements over the surface of the planet that we call winds. The **weather** then is the total effect in the atmosphere at any given time of heat, moisture, pressure, sunshine, clouds, wind, and dust particles.

Weather Instruments. — We have seen how changes in temperature may be measured by the **thermometer**, and changes in the amount of moisture by the **hygrometer**. The **anemometer** (measure of wind) is used to determine the speed of the wind. This device has four arms revolving horizontally. At the end of each arm is a hemispherical cup, generally about three inches in diameter. These vanes are connected by a steel rod with works which by indicating the speed of revolution tell the velocity of the wind. This is of great importance in foretelling the approach of storms.

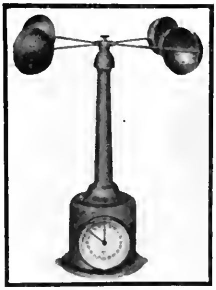

FIG. 123. An anemometer.

The instrument used to measure the weight of the air is called the **barometer** (weight measurer). In its simplest form it consists of a glass tube nearly a yard long, sealed at one end. The tube is filled with mercury and supported in a vertical position, as shown in *Figure 124*. At sea level, when the tube is filled, the mercury will fall until the scale shows a height of about thirty inches. Since nothing but air

presses down on the mercury, it must be the downward pressure of the atmosphere alone that holds it up. Whenever the weight of the air is less, the mercury level falls; whenever the air pressure is greater, the level rises. By measuring the height of the mercury we can estimate the weight of the atmosphere. This weight at sea level is a pressure of 14.7 pounds per square inch. The pressure on a grown person would be about 35,000 pounds. Were it not for the ease with which the air under this pressure penetrates the body, we should feel slight changes in pressure more than we do.

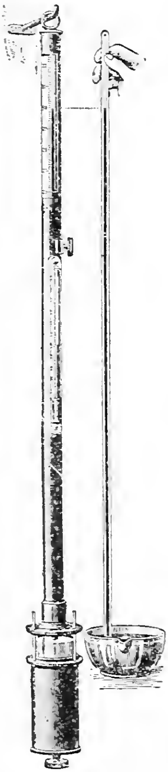

Fig. 124. A mercurial barometer.

The higher up we carry a barometer, the lighter the pressure of the air in the tube, and the lower the mercury falls. *Figure 126* shows that it falls about one inch for every 1,000 feet. It is by noting the pressure at different heights and by comparing this pressure with that at the seashore at the same time, that we can determine the altitude or height of mountains. At Leadville, Colorado, the barometer registers only 20 inches.

Another form of barometer in wide use is the **aneroid** (without fluid) barometer. In this instrument (*Figure 125*) the pressure of the atmosphere moves a delicate surface arranged over a vacuum chamber. This force is carried to the index hand moving over a dial which bears a scale similar to that of the mercurial thermometer.

Weather Conditions.—We have seen how cyclonic storms travel across the United States. We know that they are certain to come whenever a wide area of low pressure appears in the west. The low-pressure area means that over that area the atmosphere is lighter than over the surrounding region. The heavier air, from the surrounding country, flows toward this low-pressure area just as water flows from high to low levels. This causes winds to blow in from all sides. Such an area of low pressure with its clouds and rain is called a **cyclonic storm area.**

These storms cause not only rains but also hot and cold waves.

Warm winds blowing toward the low-pressure areas from the south in the winter produce thaws in our central and eastern states; and in summer bring hot spells with thunderstorms and tornadoes. After a low-pressure area has passed eastward and the storm is over (see *Figure 129*), west winds generally blow, producing winter cold snaps.

Fig. 125. An aneroid barometer.

Cyclonic storms from the Atlantic pass over the British Isles and northwestern Europe. Along the northern shores of the Mediterranean the passage of a cyclonic area is preceded by warm winds from the Sahara. Other hot winds probably caused by cyclonic storms are the **sirocco,** a hot dry wind blowing over southern Italy and Sicily; the **solano,** a similar wind blowing over Spain; and the **simoom,** an intensely hot, dry wind from the deserts of Nubia and Arabia blowing over the coasts of Arabia, Persia, and Syria. In like manner, the cyclone area is followed by cold winds in other parts of the world. Among these are the **northers,** cold winds blowing over Texas and the Mexican gulf; in Europe, the **mistral,** a cold wind in the Rhone valley; and the **pampero,** a cold wind of the Argentine republic.

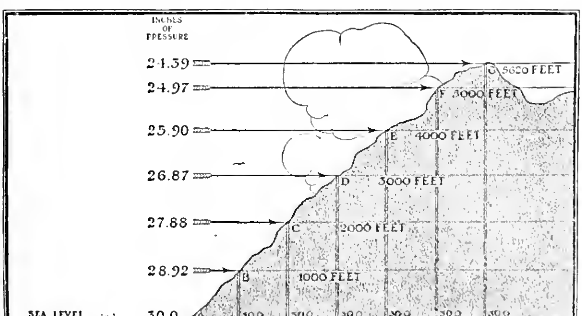

Fig. 126. A diagram showing the relation between altitude and air pressure.

Storm Predictions. — If, then, we can tell the pressure of air over the country and locate the low-pressure areas, we shall be able to predict such storms and weather changes; and by noting their general direction and speed, we can warn people of their coming. This is the very important work of the barometer and the anemometer. Toward

the center of a storm the mercury falls, due to the lightness and moisture of the air. The approach of fair weather is foretold by the rising of the barometer, due to the dryness and heaviness of the air. The anemometer telling the speed of wind permits us to work out the length of time a storm will take to pass from one region to another. The hygrometer measures for us the amount of moisture in the air at any time.

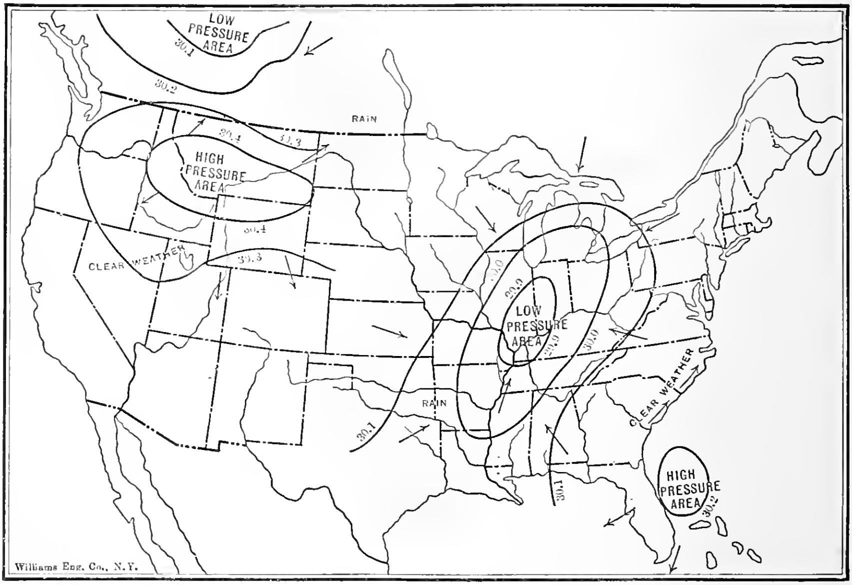

FIG. 127. A weather map of the United States. The heavy lines are lines of equal air pressure. The figures show the readings of the barometer at these places.

Barometer Readings. — A rise in the barometer shows that heavier air is drifting to a place just before occupied by light air. As heavy air has been condensed by cold, a rise therefore indicates a cold wind.

A fall shows that lighter pressures are approaching the station of the observer. This means that light air is drifting to a place just before occupied by heavy air, so that a warm wind is coming. A falling barometer also indicates a high or low pressure existing near

at hand. The fall is then due to the gradual drifting up of the lighter air and the drifting away of the heavier air in a whirl. A fall of an inch or more is enough to foretell a violent tornado. A stationary barometer indicates a continuance of existing conditions.

The Weather Bureau. — The weather conditions of the United States are of the greatest importance to the commercial and agricultural welfare of the people. Recognizing this fact, the government maintains a Weather Bureau at Washington as a special activity of the Department of Agriculture. Two hundred branch stations are scattered throughout the United States, each equipped with barometers, thermometers, rain gauges, and snow gauges, anemometers, and other instruments. At 8 A. M. and 8 P. M. every day reports on temperature and pressure, direction and velocity of winds, condition of the sky, and amount of rain or snow are telegraphed from these stations to Washington, where they are studied by weather experts who trace the paths of storm areas and are thus enabled to forecast the weather conditions that may be expected to prevail during the following 36 to 48 hours.

Weather Maps. — When the reports are received weather maps are carefully prepared. The solid black lines are traced to run through all places which report the same barometric pressures. These lines are called **isobars** (same pressure) and the figures give the barometer readings. In this way it is easy to locate the areas of low pressure, which are the storm areas. *Figure 127* shows the position of a storm area over the central states. The storm chart (*Figure 129*) shows us that this is a tropical storm from the gulf of Mexico, and should advance north and northeast. Notice the arrows, indicating how the winds blow from all sides toward the low-pressure region. Of course here the air ascends, expanding and cooling as it rises. This condenses the moisture and sends it down as rain. Farther east on the coast is a region of high pressure passing out over the Atlantic. Notice the direction of the wind and the surrounding weather conditions. Farther west is a similar area of high pressure sometimes called an anticyclone, while in the northwest there is a small low-pressure area which may be the beginning of a cyclonic storm.

Figure 128 shows the conditions on the following day. Observe the movement of the central low-pressure area. Notice how the

western high-pressure area follows it eastward and observe the movement of the northwestern low-pressure area. You will notice that the atmosphere seems to follow a regular wave form, just as we found water waves doing. The general movement of " lows " and " highs " in the United States is from west to east, resembling a huge wave, the " highs " being the crests and the troughs the " lows." These alter-

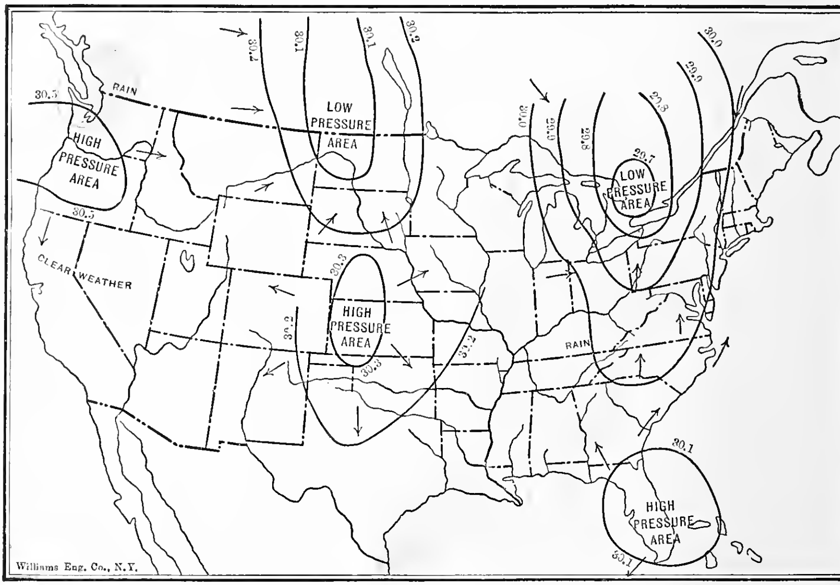

Fig. 128. A weather map for the day following that shown in Figure 127. Note the movement of the pressure areas and the storm.

nating " highs " and " lows " have an average easterly movement of about 600 to 700 miles a day.

The United States Storm Chart. — The storms of the United States follow a series of tracks related to each other by well-defined laws. The positions of these tracks have been determined by studies made in the Weather Bureau. The track that the central point of a high area or that the center of a storm follows in passing over the country from west to east is laid down on individual charts. These are collected on a group chart, and from this the average track

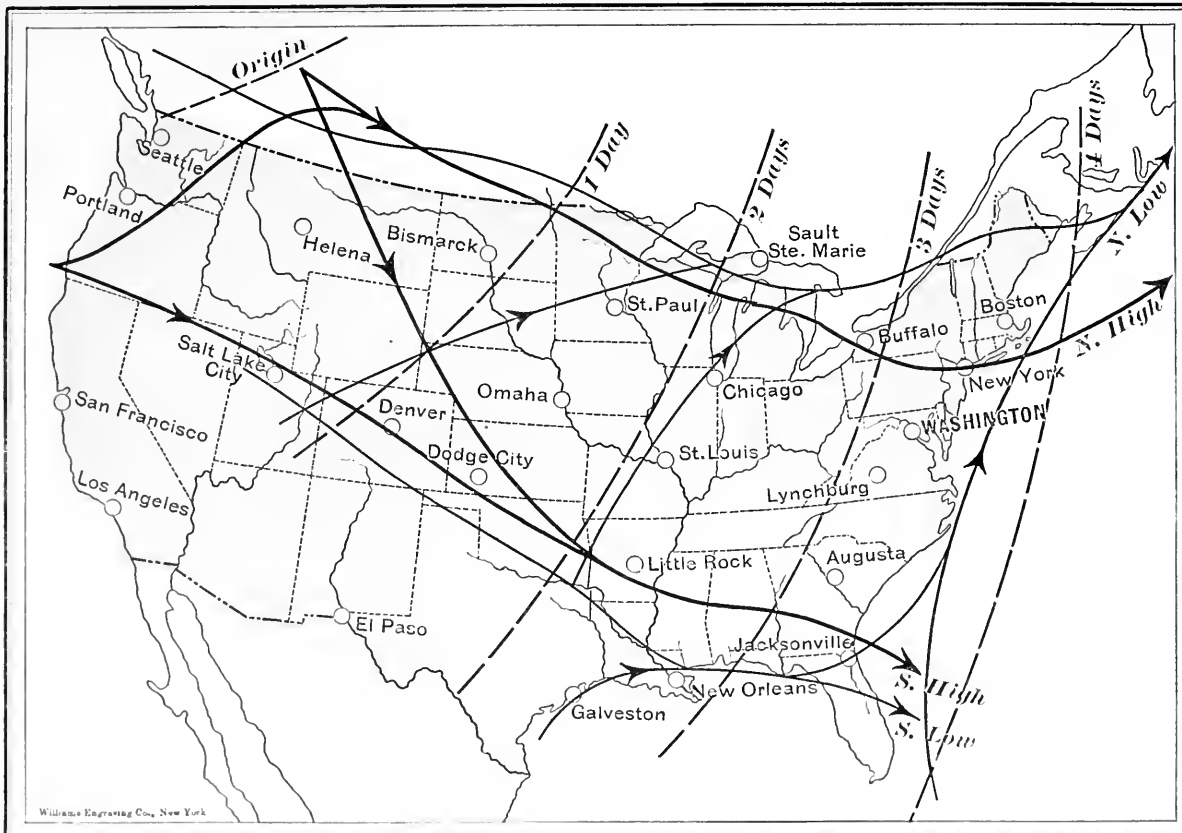

FIG. 129. A map showing the movement of storms across the United States.

pursued can be readily described. This chart indicates that there are two sets of tracks running westerly and easterly, one set over the northwestern boundary, the Lake region, and the St. Lawrence valley; the other set over the middle Rocky mountain districts and the Gulf states. Each of these is double, with one for the "highs" and one for the "lows." The transverse broken lines show the average daily movement.

Let us trace the storms somewhat in detail. A "high" appearing on the California coast may cross the mountains near Salt Lake, and then pass directly over the belt of Gulf states to the Florida coast; or it may move farther northward, cross the Rocky mountains in the state of Washington, up the Columbia river valley, then turn east, and finally reach the gulf of St. Lawrence. The paths are determined by the laws of the general movement of the atmosphere and the irregularities of the land surface. This movement of the "highs" from the middle Pacific coast to Florida or to the gulf of St. Lawrence is confined to the summer half of the year, April to September inclusive.

Importance of the Weather Bureau. — These weather maps and storm charts are sent out in great numbers and are the means of saving millions of dollars' worth of property every year by giving advance warning of changes. Farmers and gardeners are warned against frosts, ship owners against hurricanes and storms. Sometimes 100,000 telegrams are sent out to all parts of the country to give warnings. By advance notice of one cold wave $3,400,000 worth of property that would have been destroyed was saved.

Snow and ice warnings are of special interest to those interested in the winter wheat crop, to ice dealers, and to the manufacturers of rubber goods. Rainfall reports are watched by growers of cotton, corn, wheat, sugar, and rice. Storm signals are displayed at 300 points along the coast, and the warnings for a single hurricane are known to have detained in port on our Atlantic coast vessels valued with their cargoes at over $30,000,000. Flood warnings, often ten days in advance, are sent out from 500 river stations and rainfall stations so that, especially in the lower Mississippi valley, live stock and other movable property may be saved.

Effects of Weather on Man: in the Cities. — In the cities, with notice of an approaching cold wave, greenhouses are closed and boilers fired. Preparations are at once made by heating and lighting plants, whether gas, electric, steam, or hot water, to meet the increased demands that will follow. Exposed mains and general plumbing are protected. Large stockyards drain their mains. Gasoline engines are drained. Work in concrete is stopped. Brewing companies take care of exposed ammonia condensers and water connections. Street railway companies arrange for more heat in their cars. Natural gas companies turn a larger amount of gas into their lines to provide for increased consumption. Merchants curtail advertisements or direct attention largely to cold-weather articles. Oyster dealers lay in a larger stock. Coal dealers supply partial orders to all customers needing fuel, instead of full orders to a few, and thus please all their patrons. Ice factories reduce their output. The dredging of sand and gravel ceases, and iron ore piled up for shipment is placed in the holds of vessels, to prevent the wet masses from freezing solid. Charity organizations prepare to meet increased demands for food and fuel, and thus minimize suffering among the poor.

Slight changes in temperature, moisture, and other weather elements have been found to affect the quality of products. This is true of certain stages in the manufacture of bluing, varnish, oils, paper, photographic supplies, chocolate candies, and some acids. They also affect the plans of public amusement companies, excursion enterprises, awning companies, and those engaged in outdoor painting.

Lime, cement, brick, drain tile, and sewer pipe material all require protection from rain during the process of manufacture, and cement work must be protected from rain for twenty-four to forty-eight hours after the cement is laid. City departments determine the number of teams needed in street sprinkling, railroad companies guard against washouts, and irrigation companies control the output of water by expected conditions of rainfall. Physicians watch weather changes in giving advice to patients suffering with tonsilitis or inflammation of the throat, nose, or ear, where it is expedient that the sufferer should keep indoors.

Effects of Weather on Man: Transportation. — The railway and transportation companies watch weather changes in all their shipments. Perishable products are protected against temperature extremes by icing or heating, as conditions may require. Oftentimes shipments of perishable goods are hastened when it is found possible to carry them to their destination in advance of the expected unfavorable temperature conditions. When this cannot be accomplished, goods en route are run into railroad sheds for protection. A notice of a cold wave will also often hold up a contemplated shipment until after the freeze has passed; and, if the cold is protracted, the companies will refuse to receive consignments of goods likely to be injured by low temperatures. These precautions apply in some instances to prospective temperature changes within comparatively narrow limits. Bananas, for example, require very careful handling, and must be kept at a temperature of 58° to 65° during shipment, as a temperature below 55° chills the fruit sufficiently to spoil it, while a temperature above 65° inside the car will produce overripening.

Similar precautions apply to shipments of vegetables, fruits, eggs, and other products liable to damage from extremes of temperature. On the other hand, most meats are best shipped in cold weather, although the use of refrigerator cars prevents loss; and the movement of live hogs and cattle by freight is avoided, if possible, when a hot wave is expected. High temperatures are also hurtful to certain other shipments, especially fish and oysters. The shipments of eggs kept in storage are largely regulated by temperature changes, the announcement of a cold wave being usually followed by brisker shipments from western supply districts to the eastern markets, in anticipation of a rise in prices. Temperature changes and cold-wave warnings are closely watched by brewers, wine makers, and manufacturers of carbonated beverages. Wine shipments are usually withheld until danger from cold is past, as a slight frosting causes the acid wine to crystallize.

Effects of Weather on Man: on the Farm. — In the agricultural districts, weather changes affect the trucker and fruit grower especially in the spring, when the tender vegetables must be protected by covering with paper, cloth, or soil, and fruit safeguarded by smudging, irrigation, or other methods designed to maintain the

temperature above the danger point. In the fall, protection is secured in the cranberry regions by flooding the bogs until after the cold weather has passed or danger of frost is over. Many crops, such as beans and grapes, are saved by being picked in advance of the freeze; while tobacco and unmatured corn are cut at once upon advance notice of damaging cold weather. Potato digging is suspended and the dug potatoes removed from the field, and sugar cane is cut and windrowed. The expected duration and severity of freezes govern operations in the ice harvest; if the cold is to be prolonged, the ice men await the desired thickness, but otherwise the cutting will be hastened in order to secure the best possible returns under the circumstances. In the spring, changes are watched in the maple sugar industry, as the collection and boiling of the sap are more or less dependent upon weather conditions.

The temperature changes are also largely utilized by farmers at the time for the killing of hogs, by sheepmen at lambing and shearing time, and by stockmen in general at critical seasons of the year.

In the raisin-growing districts of California, the crop while drying is very liable to injury from rain, and the producers have to protect the fruit by stacking and covering the trays. Vegetables dug in dry weather are also shipped in better condition than those upon which rain has fallen after they have been taken from the ground. Broom corn is liable to damage from rain if left in the field. A heavy fall of rain upon the alfalfa crop, after cutting, ruins its commercial value.

Effects of Weather on Man: Storms and Floods. — Weather changes are watched very closely by men who risk person or property out on the water. Agents of marine insurance companies refrain from insuring cargoes after a storm has been predicted. Fishermen take steps to protect their boats and nets. Lumbermen make their standing booms secure and regulate their log towing. At lake ports, vessels load hurriedly if they can get off two to five hours in advance of offshore winds; if snow is also expected, a start of seven to eighteen hours is necessary. Considering the cost of operating a vessel whether standing or moving, a day saved from idleness in the harbor means an appreciable saving in expense.

Floods affect all river industries, as well as the operations carried

on in the plains subject to inundation. Their approach is followed by the removal of cattle from bottom lands and by the saving of such crops as can be cut before the high water reaches the threatened district. Fishermen remove their fishing gear from the water so as to avoid damage from the driftwood and logs that are brought down stream by the rise, and devote their energies to gathering this drift for sale. Along the river streets of many cities the basements of

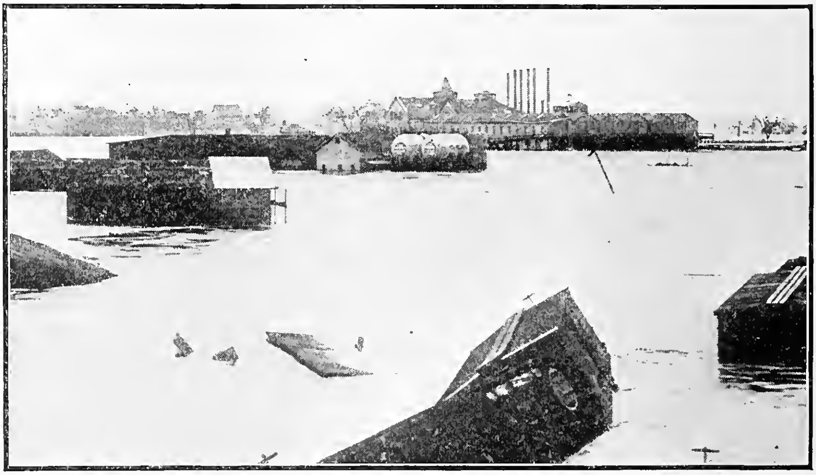

Fig. 130. The effects of a flood in the Ohio valley.

warehouses and other buildings are submerged at high water. Wood and ties piled along the river banks are made secure by the dealers. Coal barges are run aground at a desirable height, and then unloaded at leisure after the river falls. Navigation companies arrange for the transfer of their offices and landing places from the lower to the upper docks. A knowledge of slight rises is often of great value, as a small swell frequently permits large movements of water. Lumbermen cut much timber in the swamps and along the streams during low water, looking to the rises to carry out their logs. During rising water, those in charge of locks, dams, and levees are alert to the need of strengthening and protecting the property under their care. In flood periods, seiners and gill netters determine what class of gear

to use to obtain the best results, as different kinds are needed for different stages of water. Fishermen in the Columbia river claim that the water stage seems to have some effect on the entrance of salmon from the ocean, and that a spurt in the run of fish can be predicted with a fair degree of accuracy.

On the other hand, when rivers fall the drop is of considerable importance to some interests. When the stage falls below a given height many water-power plants have their water supply cut off, and are forced to employ steam power or electricity in order to continue their business without interruption. Dock building, pile driving, dredging, and repairing are largely done during low water stages, previous notice of which enables engineers to arrange for such operations.

QUESTIONS. — (1) What are the elements that make up the weather? (2) How does a barometer differ from a thermometer? (3) How does an anemometer differ from a hygrometer? (4) What is the use of these instruments in predicting weather changes? Which are the more important? (5) Why does the barometer "fall" as it is carried up a mountain? (6) If mount Shasta in California is 14,380 feet high, how would a barometer act during an ascent to the summit? (7) Why is it important to man to be able to predict storms? (8) What is indicated when the barometer falls? When it rises? When the mercury remains stationary? (9) Give some results of cyclonic storms in Europe, Africa, South America. (10) When the barometer falls in New York what weather changes may we expect? When it rises? When it falls suddenly at sea? (11) Why does an east wind in New York mean overcast skies and rain? (12) What is the probable effect of a south wind in New York? (13) Why is it so important to be able to foretell floods? (14) State the connection between floods and rainfall. (15) What are some of the effects of weather changes along the coast? (16) What effects of weather changes on the health of people have you noticed?

EXERCISES. — (1) Write a paragraph on the work of the Weather Bureau. (2) From the storm chart (*Figure 129*) make a list of the states where cyclonic storms occur frequently. Tell about the weather conditions in these states. (3) Write a paragraph on the effects of weather changes on farmers. (4) Tell how a weather map is made. (5) Make an outline map of the United States and insert the Rocky Mountains in an east-and-west direction in the southern states. What effect would this change have on our weather condition? (6) On the same map trace the Rocky mountains along the Canadian border. What effect would this change have? (7) Transpose the Appalachian mountains and the Rockies. Tell the effect of this change on our weather. (8) Write a paragraph telling how weather changes affect the manufacturer and the shipper of goods. (9) Make a diagram showing that high and low pressure areas over the United States are like a wave form.

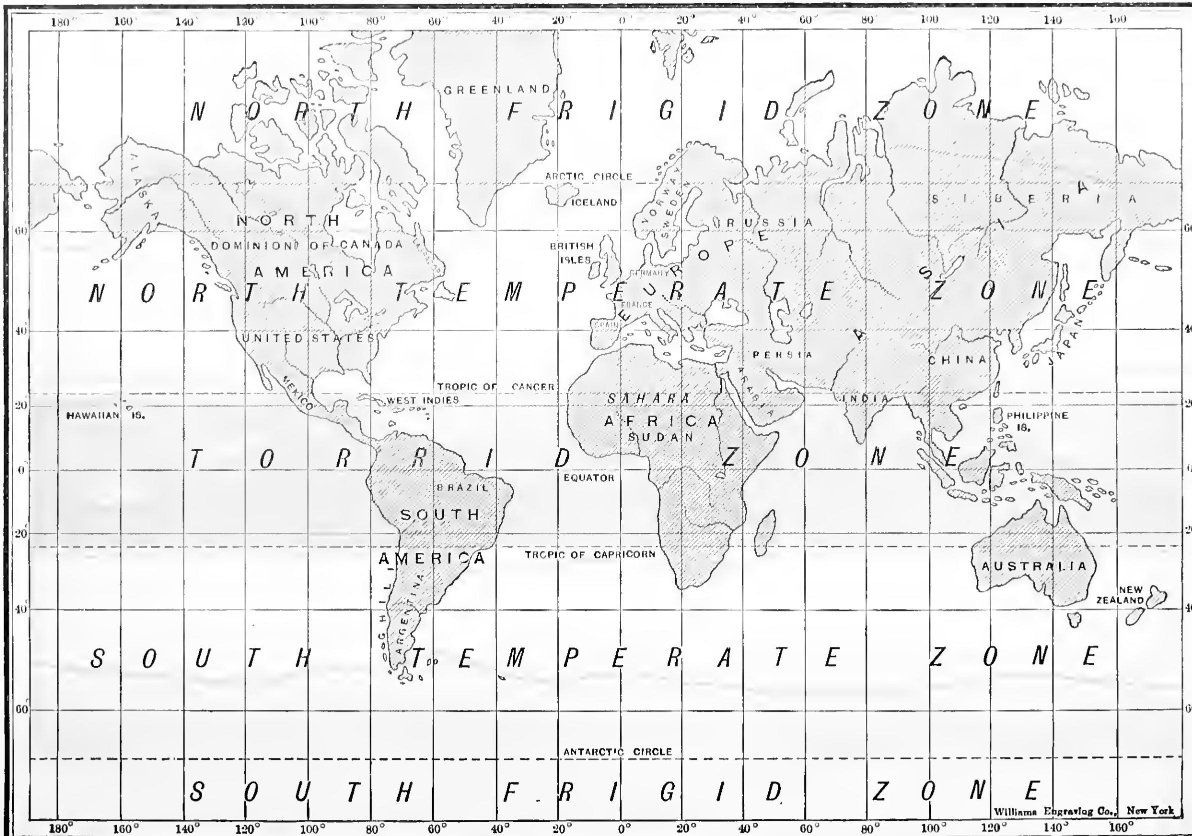

FIG. 131. A map of the world showing the distinction between the light zones and the heat belts.

CHAPTER XIII

CLIMATE AND ITS CAUSES

Weather and Climate. — We have just considered the atmospheric conditions, such as heat, wind clouds, and rain, that account for the weather. But the weather is the result of these conditions at any given time only, and we know that the weather changes suddenly, especially where the westerlies blow. The climate of a region is more stable than the weather and changes very slowly. This means that before we say that a region has a hot, rainy climate, we should observe and record the weather conditions for as long a period, perhaps, as one year. Many days might be temperate and clear, but the greater number of days would be hot and rainy. Thus the *average* of the weather in any region is its **climate.**

Light Zones and Heat Belts. — The temperature of the earth and its atmosphere depends mainly upon the direction of the sun's rays. If no other cause interfered, these rays would divide the earth into five heat belts or zones, as shown in *Figure 131.* At the summer solstice the perpendicular rays would mark the tropic of Cancer, its horizontal rays the Antarctic circle. At the winter solstice the perpendicular rays would mark the tropic of Capricorn and the horizontal rays the Arctic circle, and we should have one torrid zone, two temperate and two frigid zones. These zones are the result of the direction of the sun's rays and are, therefore, only sunlight zones and not true heat belts. They mark the limit of the variations in the slant of the rays as affording light, but they do not mark any exact boundaries between hot, temperate, and cold climates. The real heat belts you will find marked by very irregular lines which run across the map near the lines separating the light zones. In some parts of the temperate zone, there is a very hot climate, while some parts of the frigid zone have a temperate climate. On the highlands of the torrid zone the climate is often temperate or even frigid.

Isothermal Lines. — In studying weather changes we found that places having the same atmospheric pressure at any given time were connected on the weather map by lines called isobars. These were very helpful in determining areas of low and high pressure. In the same way, in studying temperature conditions we draw lines on the

FIG. 132. An isothermal or temperature chart of the United States for July.

map through all places having the same average temperature. These lines are called **isotherms** (equal heat), and a map showing them for any region is called an **isothermal chart.** Average temperature is ascertained by reading the thermometer at the same time every day for a month or a year.

It is by means of the isothermal lines that we have been able to secure the boundaries of the true hot, cold, and temperate belts of the earth which, as we have seen, do not correspond with the circles and tropics, although they run in a general east-and-west direction.

In *Figure 131*, in the broad belt known as the **hot belt,** limited by the heavy lines near the tropics, the average temperature of the year is more than 68°. You will notice that this belt is broader over the land than over the ocean, and extends farther into the northern hemisphere than into the southern.

The **north** and **south temperate belts** border the hot belt, and all places within their limits have average temperatures of more than 50°. You will notice that the north temperate belt is much wider than the south temperate belt. It influences more land areas and contains the greatest nations of the world. About the poles are the **north** and **south cold belts** in which the average temperature is always less than 50°. Here we find the south cold belt running much nearer the equator than does the northern belt.

Movement of the Heat Belts. — We have read how, at the equinoxes, the revolution of the earth brings the sun's rays perpendicular at the equator, and how at the summer and winter solstices the revolution has brought the perpendicular rays respectively to the tropic of Cancer or to the tropic of Capricorn. As a result, the heat belts also shift up and down the face of the world. In July, when the sun is high, the heat belt runs as it is shown in *Figure 138*. On the other hand, in January, it changes to the position shown in *Figure 137*. The isotherm of 70°, which passes through Maine in July, is found in January barely reaching the southern tip of Florida, farther south by 18° of latitude. We have already seen how wind and rain belts also shift north and south following the sun.

The Heat Equator. — When we find the point of highest average temperature on each meridian and then trace the isotherm connecting these points, we draw the **heat equator** of the earth. It crosses the northern part of Brazil; extends northwest to about 23° north latitude, in the gulf of California; takes a southerly direction below the equator; westerly, passing north of New Guinea; northwest until it reaches Hindustan; then north to the 23° parallel of north latitude; turns south and west across Africa at the 15° parallel of north latitude; then southwest across the Atlantic to Brazil. This line is never the same for two successive days, but swings north and south with the changing position of the sun in the heavens.

Causes of Climate Variations: 1. Latitude. — As a general

rule, the farther from the equator, the colder the climate; so that **latitude** is a very important element in determining climate. If land and water, winds and currents, did not interfere and the earth's sur-

FIG. 133. An isothermal chart of the United States for January. Compare the lines with those in Figure 132.

face were perfectly smooth, isotherms would be parallel to the equator, the heat belts and light zones would correspond, and latitude would be the only factor to consider in determining the climate of a region.

2. **Altitude.** — One very important cause for the irregular boundaries of these heat belts is **altitude,** or distance above sea level. Records made with barometers and thermometers show that as the elevation increases there is gradual decrease in temperature at the rate of about 3° F. for every 1,000 feet. There is little warm ground to give up heat to the upper-air layers. Because of this, a frigid climate is found at the equator at a height of a few miles, and highlands

are everywhere cooler than neighboring lowlands. As we ascend a mountain, then, we encounter lower temperatures, and to find the same degree of heat as on a plain, we should have to move toward the earth's equator. An elevation of 350 feet is equivalent in its effects on temperature to a difference of 60 miles in latitude. When

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FIG. 134. Subtropical plants in southern France, in the same latitude as Portland, Maine.

an isothermal line crosses a mountain range, it will bend toward the equator; when it crosses a plain, it will bend toward the poles. Trace this in the Rocky mountains (*Figure 133*).

Quito, situated on the equator, has a temperature like our May, while cities in South Dakota have temperatures ranging from 44° below zero to 110° above zero. In some of the northwestern states the temperature varies 150° during the year.

3. Distance from the Sea. — We know that the land along the

seashore soon becomes warm on a summer morning, while out on the water the air still remains cool. This is due to the fact that land takes in the sun's heat quickly and gives it up or radiates it quickly. Water absorbs heat slowly and loses it slowly. Land becomes very

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Fig. 135. The barren regions of Antarctica.

hot in summer and very cold in winter, while the water retains a more even temperature throughout the year. The farther a region is from the ocean, the more extreme its climate will be. Islands in the oceans have cooler summers and warmer winters than places in the same latitude on the mainland. In Hawaii the difference between summer and winter temperatures is about 7°. Along any seacoast the climate is always more even throughout the year than in the interior of the continent.

Thus in *Figure 137* we find the average temperature of Kamchatka in January is 10°, while in July it is 55°. In central Siberia, far from the ocean, the average in January is about 60° below zero, while in July it is about 60° above. Thus the difference between the summer and winter inland is about 120°, while in Kamchatka, near the ocean, it is about 45°.

4. **Winds, Rainfall, and Currents.** — Winds produce variations in climate, and so tend to make isotherms curve over the earth's surface instead of being straight lines. Temperature, humidity, cloudiness, and rainfall depend largely on the average direction from which the wind blows. Winds blowing over the land from the ocean tend to make the climate equal, or **equable,** throughout the year. In California, Oregon, and Washington, the British Isles and northwestern Europe, the prevailing westerlies, influenced by the ocean waters over which they blow, temper the cold of winter and moderate the heat of summer. When, however, they blow over the land, they are very cold in winter and hot in summer. For this reason Labrador is barren and desolate, receiving the cold westerlies from the interior of Canada; while in the same latitude in Europe, great cities and agricultural regions exist.

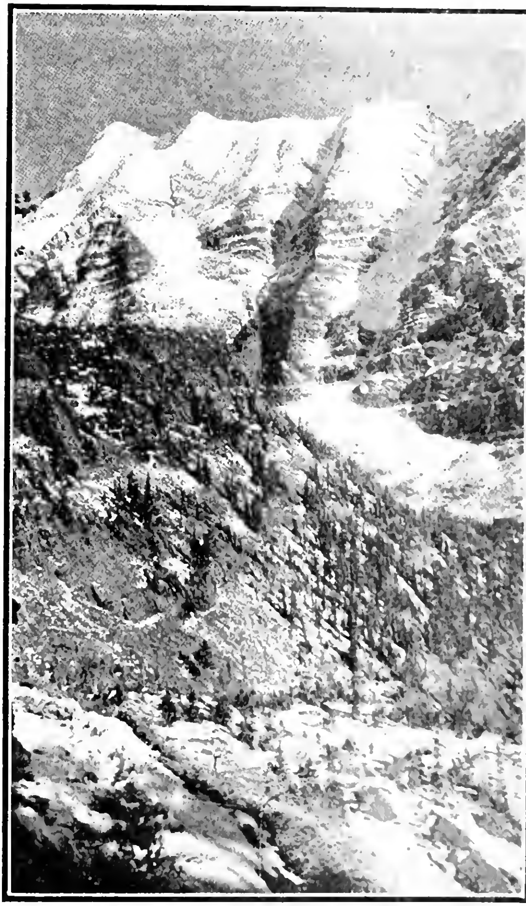


FIG. 136. A part of a mountain range which affects climate by acting as a barrier to winds.

Ocean currents, as we have seen, affect climate by carrying water from one zone to another, because winds blow over these currents

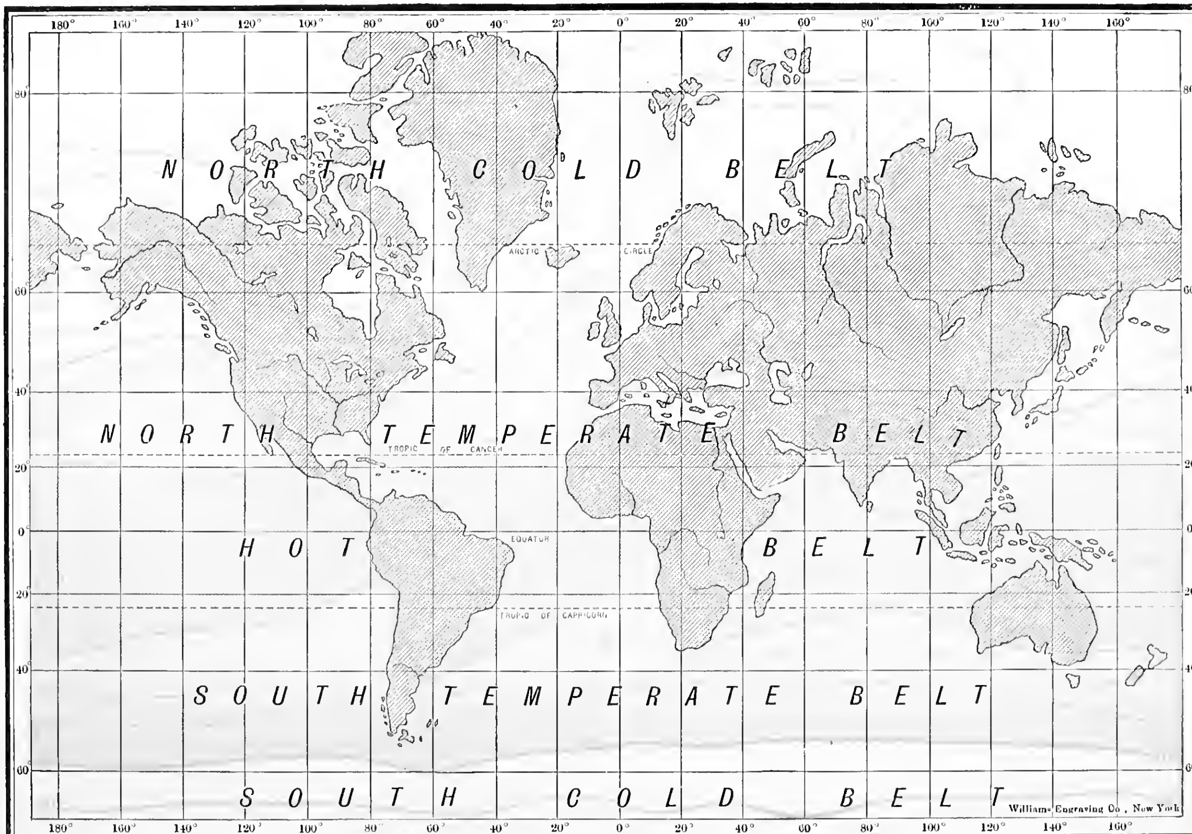


FIG. 137. A map showing the isotherms of the world in January.

and have their temperature influenced. Then, blowing upon the lands, they influence their climate. Note, again, in *Figure 122* the direction of the warm north Atlantic drift and then observe its effect on the isothermal lines in *Figure 137*, off Norway and up into the Arctic ocean. In *Figure 138*, off the eastern United States, you note the bend of the lines toward the equator due to the cold Labrador current.

5. **Highlands** always affect the climate of the neighboring regions. The Alps act like a great back door to Italy, southern Spain, and France in shutting out the cold north winds and checking the southern winds that would carry north the warmth from the Mediterranean waters. In the same way, the equable climate of California, Oregon, and Washington is not enjoyed by the states farther east on account of the mountain barrier which prevents the moist westerlies from influencing the inland parts. The summers then will not be tempered by the ocean winds, and the winters will be much colder than those along the coast. Again, we have seen how highlands affect the distribution of rainfall. The moisture of the atmosphere condenses on the windward side of mountains, leaving the other side more or less arid.

UNITED STATES ISOTHERMAL CHARTS. — (1) In *Figure 133* note the isotherm of 30°. Why is it so much colder in the interior than on the east coast? (2) What causes account for the warmth of the west coast? (3) Explain the course of this isotherm in crossing the Rockies. (4) Compare with this the effect upon it when crossing the Appalachian range. (5) Note the direction of the 40° and 50° lines on the western coast. Explain why they run parallel to the coast. (6) Account for the curve of the 20° line over the Great Lakes. (7) In *Figure 132* trace the course of the 60° line. (8) Find the difference in latitude between the northern and southern limits of this isotherm. (9) Explain why southern California and Maine should have the same temperature in July. (10) Account for the two southerly bends in the isotherm of 70°. (11) Find the difference between the summer and winter temperatures on the western coast. Find the difference on the eastern coast and compare the two. (12) In general, how do isotherms bend in crossing the United States? Why? (13) Trace the course of the isotherm of 80° and account for its irregularities. (14) Give two reasons for the turning of an isotherm to the north when it crosses a desert region.

World Isothermal Lines. — In these charts we have lines traced all around the world, all places on a given isothermal line have the same summer or winter temperature. We have learned that in winter the land is colder than the ocean. This explains why in *Fig-*

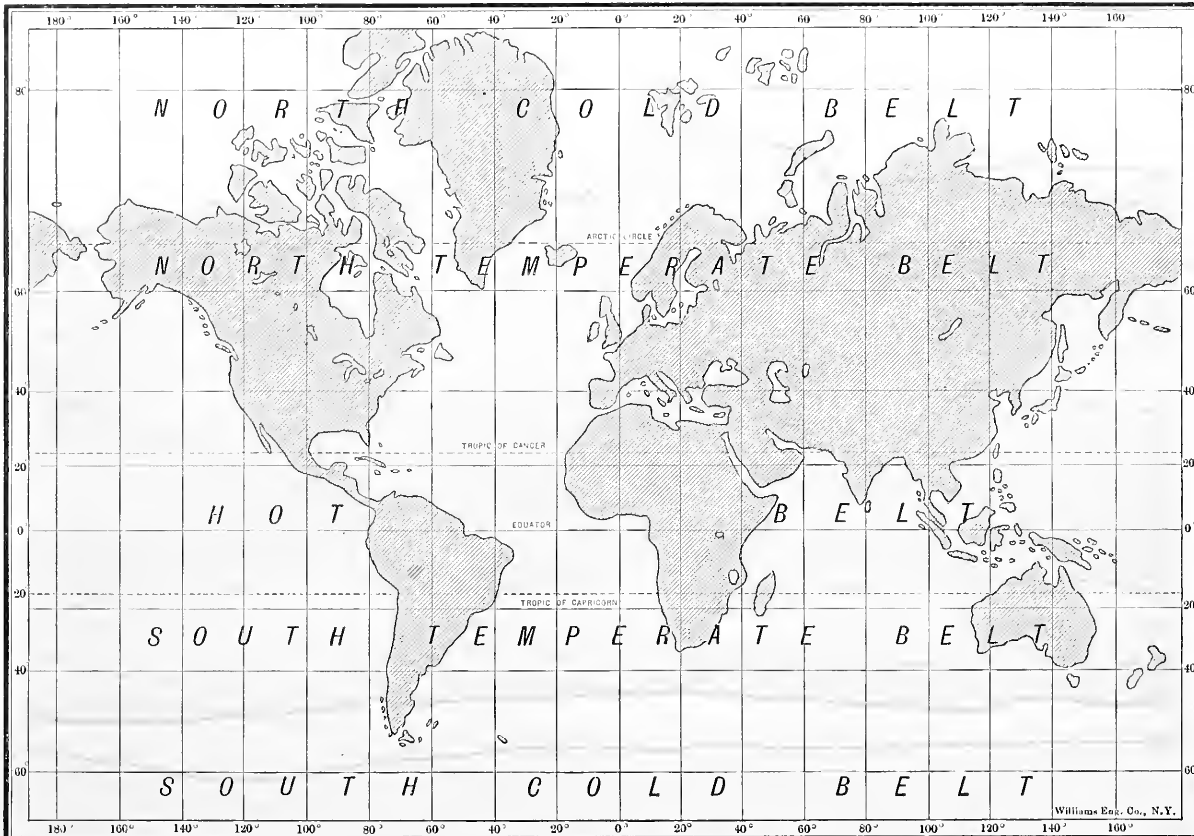


FIG. 138. A map showing the isotherms of the world in July.

ure 137 the isotherms bend toward the equator in passing over the continents. The ocean gives up its summer heat slowly but the land very quickly, so that the line must bend toward the warmer equatorial regions to meet the same temperature there. In *Figure 138*, in the summer, the continental isotherms bend away from the equator because the land is now hotter than the océan water. Notice the isotherms bending toward the equator where they cross the mountain ranges. In the southern hemisphere where there is less land to interfere with climatic conditions, note how regularly the lines of equal temperature pass around the earth. Compare the 70° lines in the northern and in the southern hemisphere.

On the ocean, we should expect to see isotherms more regular than on land, though affected by warm and cold currents. Note the effect of the Japan current and the Gulf Stream in *Figure 137*. Note how the cold Labrador current pushes the lines to the equator while the Gulf Stream drives them north. These currents produce a great difference in temperature between our northern and southern coasts. In the southern hemisphere, note that the isotherms crossing the ocean run almost parallel with the circles of latitude.

The Climate of Different Countries.—Taking into consideration the latitude, altitude, distance from the sea, and prevailing winds, describe the approximate climate of the following countries:

1. Brazil
2. Sweden
3. South Africa
4. Canada
5. Australia
6. Germany
7. India
8. Russia
9. Argentina
10. Italy
11. Japan
12. France
13. Siberia
14. Spain
15. Mexico
16. China

Verify your results from the rainfall and isothermal charts.

QUESTIONS. — (1) In what ways does the climate of New York differ from its weather? (2) Explain the difference between isotherms and isobars. (3) What is the difference between a heat belt and a light zone? (4) Why is it that the tropics do not really separate the heat belts? (5) Name five causes which make irregular the lines separating the heat belts. (6) Give reasons why places with the same altitude may have different temperatures. With the same latitude. At the same distance from the sea. (7) How is an isothermal chart constructed? (8) How do these lines bend in crossing mountains? In crossing continents? In crossing small islands? (9) What causes may

affect their regularity in crossing the ocean? (10) How do mountain ranges affect rainfall and climate? (11) Why do the heat belts move in January and June? (12) How does the heat equator differ from the geographical equator?

EXERCISES. — (1) Note the northern isothermal of 50° in *Figure 137*. Account for its variations around the world. (2) Name the states and countries through which the northern isotherm of 40° passes. Explain why these places should have the same temperature. (3) Account for the regularity of the 70° northern isotherm. For the irregularity of the 70° southern isotherm. (4) Note the circular isotherms in Australia and Africa. Explain why they should be found in these places. (5) Explain the isothermal lines on the northern coast of Russia. (6) Why are the isotherms so close together off the North American coast and so widely separated off the European coast? (7) In *Figure 138* explain the 60° isotherms in the northern and southern hemispheres. (8) In *Figures 137* and *138* can you observe any effects of the winter and summer monsoons in India? (9) Why is it that oranges grow in Italy which is in the same latitude as New York, while the latter is visited with killing frosts for several months of the year. (10) In *Figure 137* explain the effect of ocean currents on the isotherms along the west coasts of the United States, South America, and Africa.

CHAPTER XIV

THE EFFECTS OF CLIMATE ON PLANTS

The Controlling Power of Climate. — Climate exerts a control over all living things on this planet, because it comprises the three elements, light, heat, and moisture, upon which their life depends. We are to see now how the factors of climate affect plants, animals, and man.

The Needs of Plants. — Since air is everywhere present over the

FIG. 139. A bamboo grove in the torrid zone.

earth, plant life would exist everywhere did not other conditions interfere. We know that plants cannot live where the temperature is

freezing, because the sap is chilled, so that the nourishment from the roots is kept back. Again, plant life is destroyed when subjected to a temperature near the boiling point, because such heat causes changes which deprive the tissues of their power of action. Sunlight is of great importance, because by its aid the green cells change carbon dioxide into carbon and oxygen. Notice the bamboo branches in

Fig. 140. Harvesting sugar cane in Cuba.

Figure 139 bending to secure their share of the sunlight. The sap is the blood of a plant, carrying food and other material to stem and leaves. No plant can live without water, for the sap is largely composed of water. Although soil is not necessary to all plant life, the great majority of land plants depend on it for water, food, and anchorage. Plant life, then, depends upon the heat and light of the sun, the air and its moisture, and the soil.

Some low species are able to survive in many climates; but most plants are fitted to exist in only one set of surroundings. These thrive best where the soil, temperature, and moisture are best suited to fur-

nishing them the necessary food. The sugar cane (*Figure 140*) requires a warm, damp climate; cotton needs warmth and sun but can stand a lower temperature; corn, though requiring a long warm summer, grows much farther north than cotton; and wheat may be raised in a climate where corn would die from low temperatures.

In this way we see there are zones of plant life similar to the belts

Am. Mus. Nat. Hist.

FIG. 141. The dense tangle of the tropical forest.

of temperature. Each zone has its own characteristic forms of vegetation, and from the polar regions to the equator there is a regular gradation of plant life. We do not find the same forms in all the continents, because numerous other influences tend to vary them in different regions.

Plant Life in the Torrid Zone. — Since plant life depends so largely upon heat and moisture, we should expect to find the extensive and dense **forests** of the world in the equatorial rain belt. Here

grow in wild luxuriance palms, palmettoes, mahogany, teak, rosewood, banana, rubber, and dyewood trees. The daily rains and the twelve-hour stretches of sunshine produce the densest kind of jungle growth. Along the Amazon and the Kongo, and in Java and the neighboring islands, besides the trees, the vines, bushes, and grasses cover the ground, and creepers twine around the limbs, the whole

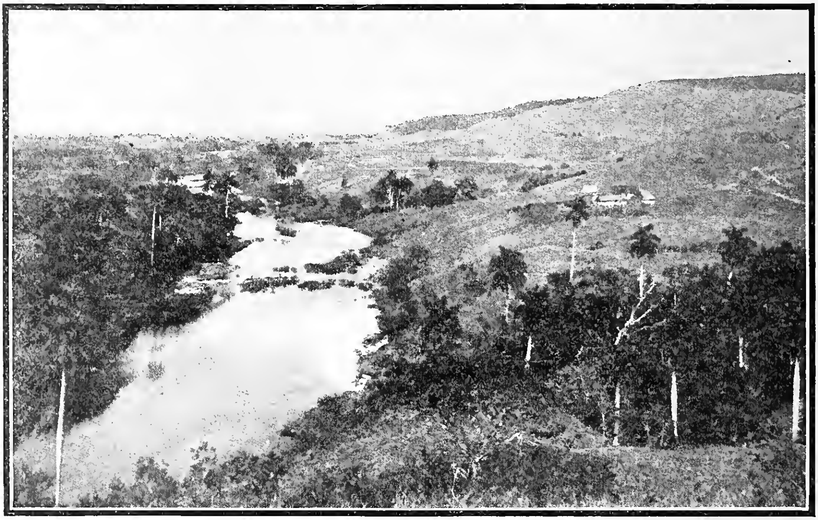
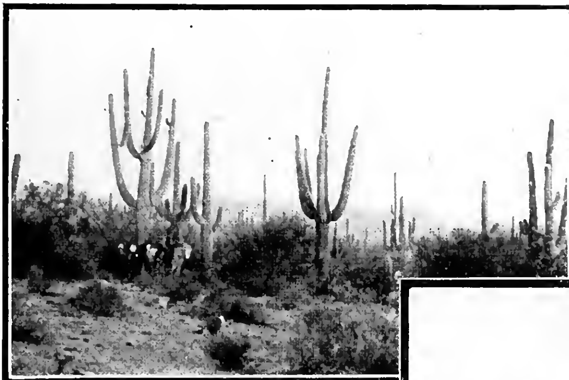


Fig. 142. In the South American savanna belt.

forming an almost impenetrable growth. The forests are damp, dark, and gloomy. There is no one season of growth, no season when all the leaves fall. Blossoms appear and shoots take root at any time. As a result of their struggle to reach the air and light, the trees grow to a great height, and increase in diameter to support their height. They lift up the dense tropical jungle with them, and make an interlacing canopy above and an intricate tangle below.

Grasslands or Savannas. — On either side of the tropical forest there are belts in which the temperature is always high, but where the seasons are called the **dry season** and the **rainy season.** Owing to the lack of rain during one season, dense forests are impossible; but some plants, such as grasses, thrive. These lands, dry

and barren in the dry season, fresh and green in the rainy season, are known as **savannas.** The campos of Brazil, the llanos of Venezuela, and the park lands of Africa lying both north and south of the equator are examples. In this belt the rainfall ranges from ten to forty inches a year, the rainy season lasts only a few weeks, and for the greater part of the year the vegetation is dried up to a brown tint except along the borders of streams. These are the great pasture lands of the world, because the grasses manage to exist, bridging over the dry season by means of bulbs and seeds which maintain a spark of life.



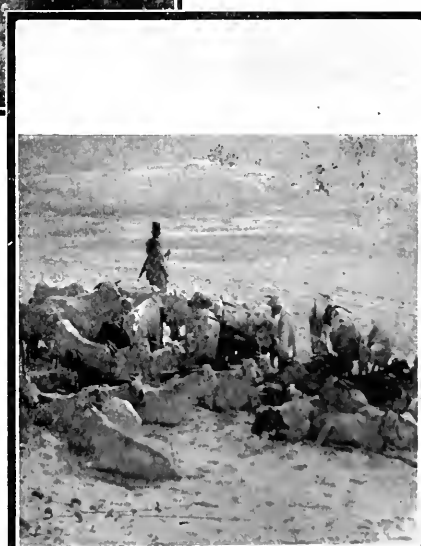


FIG. 143. Giant cacti of the southwestern United States. FIG. 144. An African desert.

Desert Vegetation. — North and south of the savanna belts are the desert regions of the world. We have seen how these are the results of the westerlies and the trades blowing constantly over the land, or depositing their moisture on some mountain barrier. You can determine their location, generally in the interior of continents, by the small amount of rainfall (*Figure 108*). The sunlight, the temperature, and much of the desert soil are favorable to plant life, but water is lacking.

This is proved by the fact that even in deserts vegetation thrives wherever there is fresh water, as along the banks of streams or where irrigation has been introduced.

In desert regions little vegetation grows except on the higher mountains. Where it does exist, it is in the form of coarse grass and spiny cacti or similar plants, although there are some shrubs and bushes. In the few places where water comes to the surface, we have small green spots called oases. The rest is made up of vast areas in which the sand is drifted by the wind into hills or dunes. Parts of the desert are broad plains, but there are also stony plateaus, deep valleys, and mountain ranges. These mountains and high plateaus rising from desert lands may have rainfall enough for forest growth. On the lower slopes the trees are stunted, scrawny, and scattered. Higher up the forest becomes dense. If the mountains are high, tree growth may be checked above by the cold.

Fig. 145. A sage brush steppe in South Dakota.

Vegetation and Altitude. — As the climate varies at different altitudes on mountain or plateau, so the plant life changes at various heights above sea level in all the belts. The plants of several different vegetation regions, like forests, savannas, and deserts, may exist along the slopes of any high mountain while the top may be covered with ice the year round. *Figure 136* shows us the barren top of a peak in the Rockies, and below it the **timber line**, or the line above which trees do not grow. *Figure 45* also shows various kinds of vegetation on the side of a mountain. Since it is the amount of available moisture that determines the conditions favorable to forest, savanna, or desert, the windward side of mountains receiving the moisture-filled ocean breezes is usually forested, while the leeward side may be barren for lack of rain.

Plant Life in the Temperate Belts. — As we move north or south from the savanna and desert belts, we come into the forest belts, in the temperate zones. Owing to the moderate rainfall and also to the severity of the climate, the forest is more open than in the tropical zone. The abundant rainfall, well distributed throughout the year, and the supply of sunshine enable the temperate belts to produce a large portion of the food products of the world.

FIG. 146. A hard-pine forest in the temperate belt.

In the forests near the tropical region the trees are more like those of the torrid than of the cool temperate zone. In the cooler parts

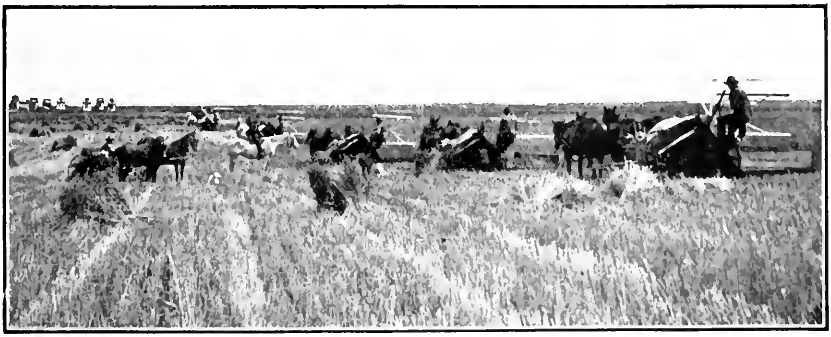


FIG. 147. A harvesting scene on the Manitoba prairies.

they are all of hardy varieties, — some **evergreen**, which have needle-like leaves that remain green throughout the winter; others **decidu-**

ous, whose leaves first change color when the frost comes, and then fall. Among the common evergreens are the spruce, pine, fir, hemlock, and balsam. Deciduous trees include the oak, maple, chestnut, elm, and walnut. There are also many fruit trees, like the apple, pear, peach, and cherry. In the cleared lands and plains of this belt are

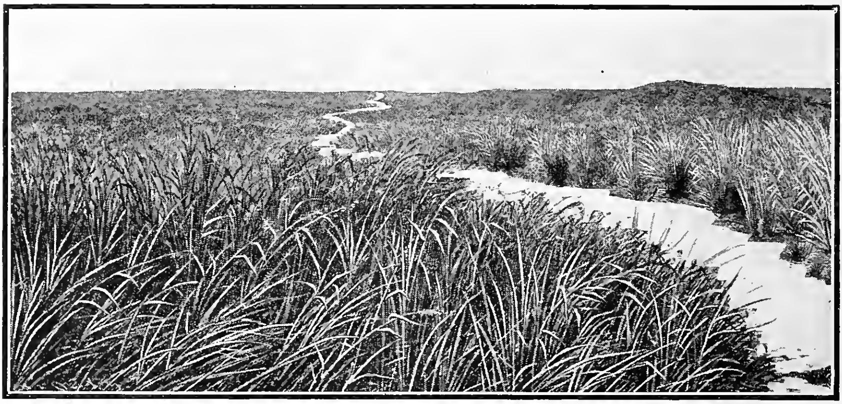


Fig. 148. The Baraba steppe, a flat plain between the Ob and the Irtish rivers in Siberia.

the great agricultural regions, where corn and wheat are extensively raised.

On the west coast of the United States the damp equable climate and absence of strong winds encourage the growth of the "big trees." In southeastern Australia, where exactly the same conditions exist, similar great trees are found.

In some parts of these regions we find great treeless plains called prairies or steppes, even though the rainfall is heavy enough for tree growth. These steppes, given over to grazing and agriculture, extend over a large part of our western states, and east, west, and north of the Caspian sea. They are found in south Africa, eastern Australia, and they are the pampas of Argentina.

Plant Life in the Cold Belt. — As we approach the cold margins of the temperate belts, we find that the deciduous trees disappear and only the evergreens survive in a timber line of low, scraggy trees struggling for existence amid unfavorable surroundings. Finally

all trees and bushes are left behind, and in the cold belts we find that all plant life is practically dead for two thirds of the year, while the temperature is below 32°. In the short summer of a few weeks, in June, July, or early August, plants spring up in a thin surface layer of soil from which the frost has been melted. This is the **tundra region** north of the Arctic circle. Lichens cling to the rocks and many mosses and water-loving plants live in the swampy soil. There are grasses, numerous flowering plants, and dwarf willow and birch trees. These cling close to the ground, not rising high, because it is important that the first snows shall cover and protect them from the cold blasts of winter. Three feet beneath this sparse growth of plant life frost is always present in the soil.

Fig. 149. A view in Greenland showing the bare rock surface with lichens clinging to it.

Summary of Plant Zones. — The three necessary elements of climate which all living things demand are light, heat, and moisture. In proportion with the supply of these elements we have seen that the land surfaces of the globe are divided up into a number of belts,

each marked by some special form of plant life. These are (1) a **forest** belt in the equatorial region, (2) a savanna or open **grassland** belt on either side of the forest belt, (3) an uneven stretch of **sand deserts**, (4) a belt of **steppes** in the interior of the great continents, (5) a belt of cleared plains and **woodland,** (6) a **tundra** belt toward the Arctic circle, (7) **snow deserts** around the poles.

QUESTIONS. — (1) What are the conditions that produce the equatorial forest belt? (2) What conditions of climate produce the savannas? (3) Mention the countries north and south of the equator in which we find savannas. (4) Describe the plant life of the savannas. (5) Account for the causes of deserts. (6) Describe the vegetation found in them. (7) Make a list of the great desert regions of the world. (8) Suppose you should climb a peak of the northern Andes, tell what conditions of plant life you would observe during the ascent. (9) Describe the observations of plant life you might make in crossing the Andes from Brazil into Peru. From Chile into Patagonia. (10) Mention the plants of the hot belt that supply food or clothing. (11) Name the trees of the temperate belts that you have seen. (12) Describe any changes in the trees you would be likely to notice in climbing Pike's Peak. (13) Name the grains and fruits of the temperate zone upon which man depends largely for food. (14) In what other ways is man dependent on plant life? (15) Make a list of the tundra regions of the earth. (16) Why is the summer so short in these parts? (17) Make a list of some of the plants or trees that supply man with drugs. (18) Do you know of any effects produced by the cutting down of forests?

EXERCISES. — (1) If the inclination of the earth's axis were 45°, what effects would be observed on the plant life of the world? (2) Make a diagram similar to *Figure 107*, but instead of winds insert the belts of plant life. (3) Make a list of woods used for furniture. State their qualities and the plant belts from which they come. (4) On an outline map of the world mark the campos, llanos, steppes, and prairies. (5) On an outline map color all the desert regions. (6) Describe the different zones of plant life you would meet in traveling through South America along the meridian of 60°. (7) The meridian of 100° through North America. (8) The meridian of 20° through Africa. (9) The meridian of 20° through Europe. (10) Wheat requires an annual rainfall of from 20 to 40 inches. Refer to the rainfall map and list the countries in which wheat is raised.

CHAPTER XV

THE EFFECTS OF CLIMATE ON ANIMALS

The Control of Climate over Animals. — We have agreed that without the light and the heat of the sun, life could not exist on this planet. Plants depend on the light and moisture, and in turn all animals derive their food directly or indirectly from plant life. They need air, water, and heat; and, though unlike plants, they are able to move freely from place to place and to maintain a certain temperature in their bodies, still climate exerts a powerful control over them, and restricts them to certain well-defined areas. Their distribution over the earth is, of course, closely related to the distribution of plant life. The flesh-eating animals, also, depend upon plants, because the weaker animals that furnish them food derive their living from grass and other vegetation.

Their Adaptation to Surroundings. — Like plants, animals are adapted or changed in many ways to meet the climatic and other conditions of their surroundings. Some, to survive freezing temperatures, are protected with a covering of fur, feather, or fat. Most water animals and many land animals are cold-blooded and can change their temperature with their surroundings. Some of these require so little air that they obtain all they need from the water; while the warm-blooded animals take out oxygen from the air they inhale, their warmth being due to slow combustion in their bodies caused by the oxygen. The bodies of animals are widely adapted to their mode of life. Wings are developed for flying; fins, scales, and boat-shaped bodies for swimming; long legs for running; and arms, claws, and tails for climbing. In the polar regions, animals are white, like the bear and the ptarmigan; in the desert regions they become a grayish brown; in the steppes and prairies they are a lighter brown; in the tropical forests many of the birds and insects are green, in imitation

of the foliage. The effect of this variation in color is to render them less easily seen by their enemies.

The Distribution of Animals. — The spread of animals over the earth is interfered with by the same climatic barriers as in the case of plants. Rivers, oceans, mountain ranges, deserts, and tropical forests are the great barriers that exclude animals from different regions. Sometimes animals pass these barriers; they may be carried from one place to another, like birds, by wind or sea; by ocean or river currents, like animals on floating tree-trunks; or they may be accidentally or purposely carried by man from one region to another. In this way, the rabbit was introduced into Australia, the brown Norway rat into this country, and cattle and horses into Argentina.

Animals accustomed to a warm climate cannot cross to the other side of a cold, rugged mountain range; the tropical forest is a barrier to the desert animal; and the desert cannot be crossed by one that needs water every day. Domestic cattle would soon perish in Greenland, where the musk ox seems not to suffer at temperatures 80° below zero. Polar bears brought to temperate regions must be constantly supplied with ice. Owing to its separation from the mainland, Madagascar possesses animals entirely distinct from those of the neighboring coasts of Africa. Finally, there are the two great invisible barriers of heat and food supply. The climatic conditions of the north and south temperate belts are about the same, yet we cannot imagine their different animals intermingling, on account of the climatic barrier of the intervening hot belt.

The Regions of Animal Life. — In considering the distribution of animals as affected by climatic conditions, we divide the earth into five great regions: the North American region; the Eurasian region, including Europe, northern Asia, and northern Africa; the South American region; the African region, embracing that part of the continent south of the Sahara; the Oriental region, including India and southeastern Asia; and the Australian region.

The isothermal lines which indicate the conditions of heat, moisture, and vegetation cannot be taken as the actual boundaries of animal life, as they do not take into account the changes produced in the species of animals by the various natural barriers we have spoken of.

FIG. 150. Some animals of the North American region.

These lines could be used only if the earth were all land surface without any irregularities.

1. **The North American Region.** — No animals live in the interior of Greenland, but in and near the Arctic ocean there is much life. The polar bear, walrus, and seal live on the ice; the musk ox, caribou, hare, and fox live on the bare tundras, while the birds, like the wild geese and ptarmigans, migrate to the south in winter in search of food. No reptiles live here, because of the great cold.

In the temperate belt animal life is more varied. The wolf, fox, grizzly and black bear, lynx, cougar, moose, elk, and deer are found here. The Rocky mountain sheep and goat, antelope, opossum, beaver, and otter are among the characteristic animals. Many rodents are found, such as prairie dogs, rats, squirrels, and rabbits. The eagle, owl, and wild turkey are among the large birds; and there are hundreds of varieties of small birds, many of which are helpful to man. They live on insects that are harmful to plant life, and they eat the grubs which develop into destructive insects if not destroyed. Practically all of these birds are migratory; and while naturalists do not agree fully as to the reasons for their migrations, we do know that they travel in search of warmth and food, and climatic conditions that tend to afford protection in raising their young. Among these are the woodpeckers, the thrushes, the sparrows, the finches, the warblers, the blackbirds, and the orioles; the hawks and the vultures; game birds, such as the partridge, the quail, canvas-back and redhead ducks; as well as other aquatic birds, such as the gulls, the tern, and the heron.

2. **The Eurasian Region.** — The animal life in the Arctic zone of this region is the same as that found in the cold belt of North America. In the temperate belt, which is of enormous extent in this region, reaching through nearly one half of the earth's circumference, there is a wide range permitted to its animal life because of the absence of any north and south barriers. In addition to most of the animals of the North American regions, there are the European bear, reindeer, hare, ibex, and the chamois of the Alps. The dromedary, camel, yak, and wild horse are found in the eastern part. In general, this region is the home of the hoofed grass-eaters. Beasts of prey

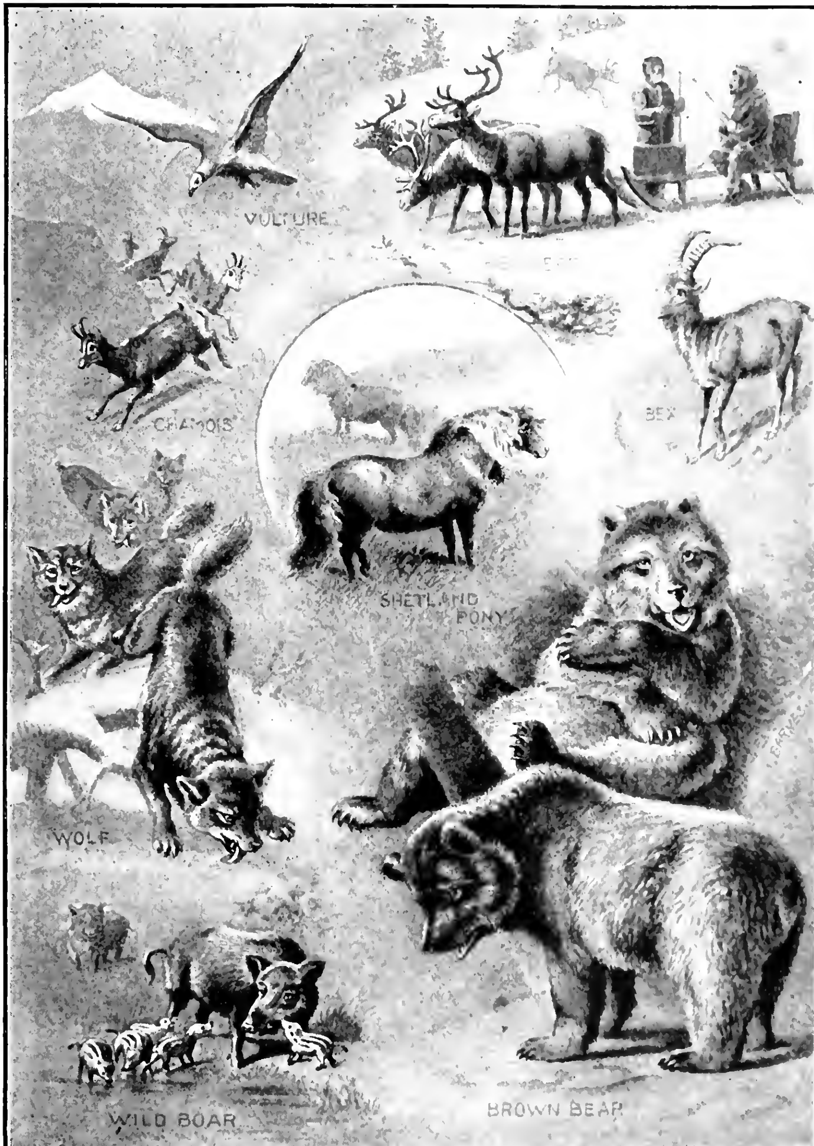


Fig. 151. Some animals of the Eurasian region.

are few and inferior in size. Man has killed off the flesh-eaters and bred the grass-eaters.

3. **The South American Region.** — Here the great forest, open grassy plains, great mountain region, and tropical areas support a wide variety of animal life. The chinchilla, alpaca, llama, and vicuña, all related to the camel family, inhabit the slopes. The monkey, the armor-covered armadillo, the sloth, the ant-eater, and the tapir are found. The jaguar is the only dangerous wild animal. The rhea is called the American ostrich; the huge Andean condor lives there, as well as humming birds, macaws, toucans, parrots, and umbrella birds. The boa constrictor, anaconda, alligator, and lizard are among the reptiles. Insect life is exceedingly varied.

4. **The African Region.** — Here we have a vast desert tract in the north, an equatorial forest region, and then belts of open savanna and prairie land. The region is remarkable for the development of its flesh-eating and its hoofed animals. The former are represented in the lion, leopard, panther, hyena, jackal, and wolf. Among the grass-eating animals are the long-necked giraffe, the buffalo, and the many varieties of antelope like the gazelle, the hartbeest, the horned gnu, the eland, and the springbok. The striped zebra, the smaller quaggas, and the wild ass are among the horse-like animals. The man-like gorilla, the chimpanzee, and the monkey, the five-toed elephant, the hippopotamus (river horse), and the rhinoceros (horned nose), dwell here. Among the birds are the ostrich, the hornbill, the secretary bird, the parrot, and the plantain-eater. The reptiles include the puff-adder, the boa, the python, the lizard, the crocodile, and the chameleon. No other region rivals this for the ferocity, strength, and size of its animals. Madagascar, owing to the water barrier between it and the mainland, possesses a different animal life. The lemur, a monkey-like, night-prowling animal, is characteristic of it.

5. **The Oriental Region.** — The animal life here resembles that of Africa, since the physical conditions are similar. A luxuriant tropical forest covers much of the country, and open pasture lands are found in some of the mature river valleys. Here are found the lion, cheetah, tiger, rhinoceros, leopard, and the Indian or three-toed elephant. The long-armed gibbon and the orang-outang are found in the East Indies.

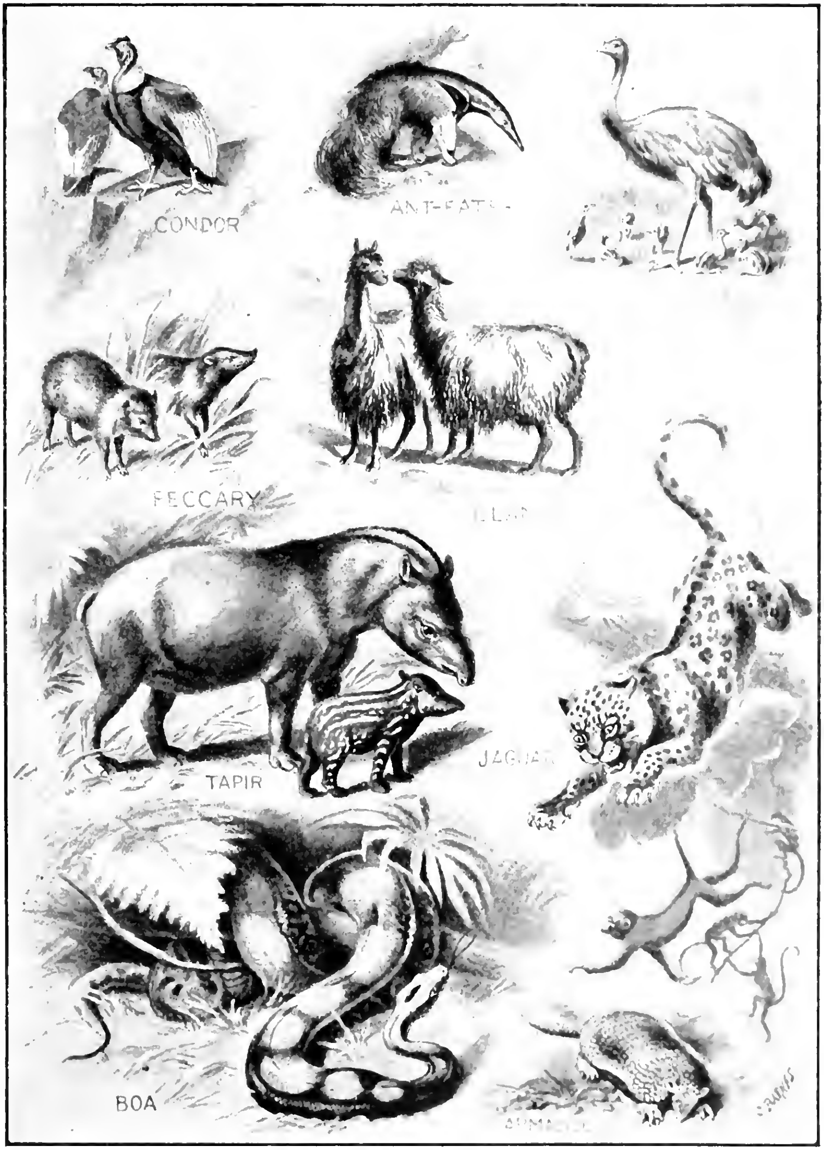


FIG. 152. Some animals of the South American region.

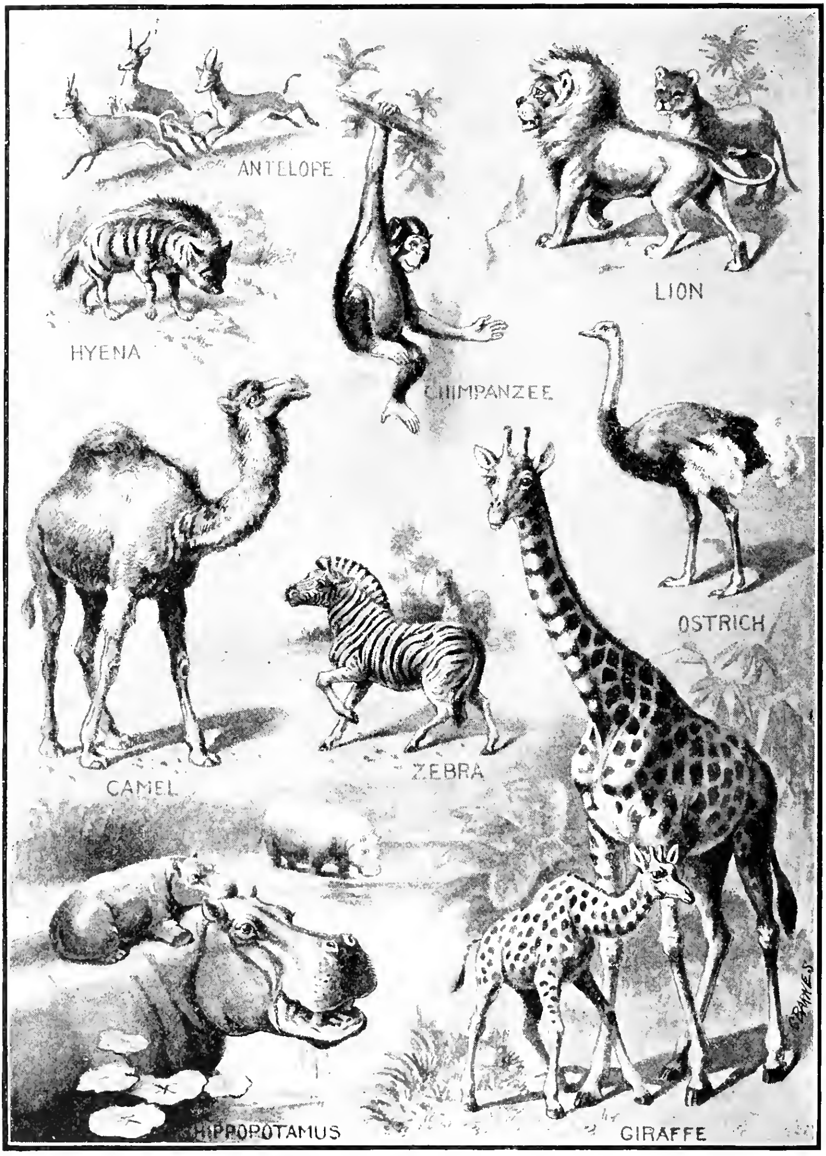


FIG. 153. Some animals of the African region.

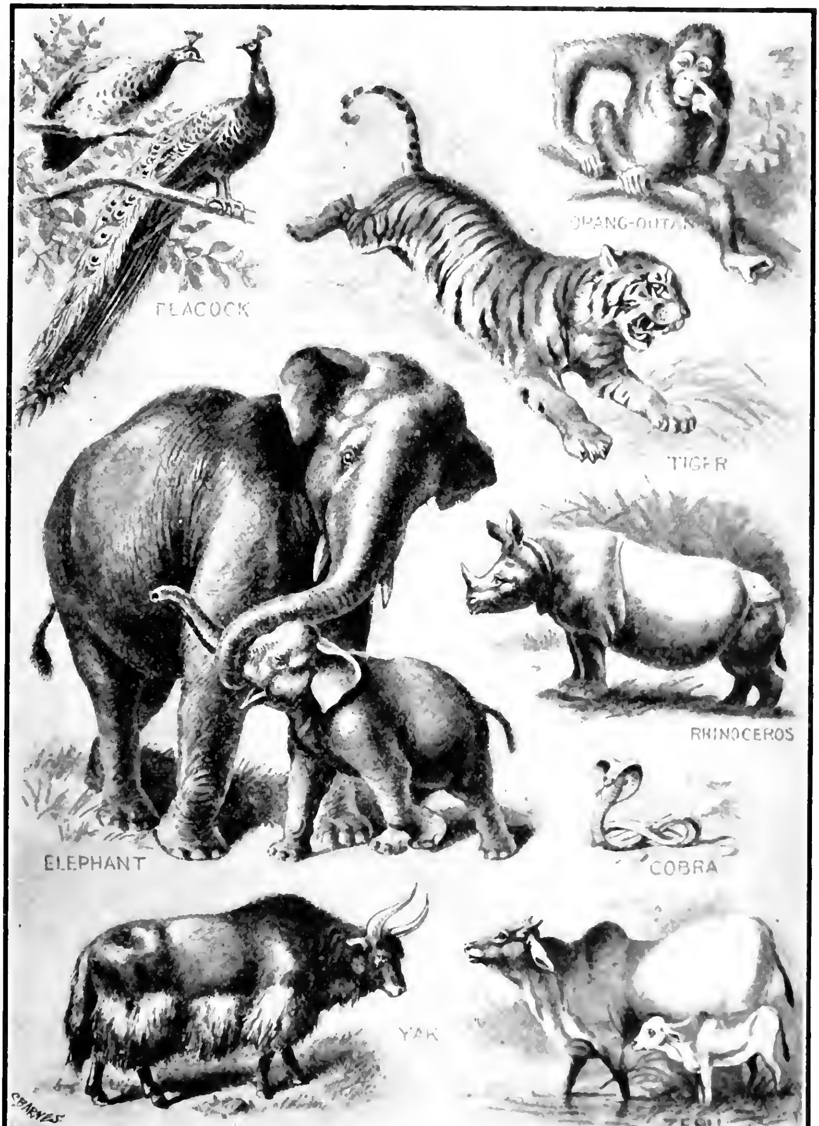


FIG. 154. Some animals of the Oriental region.

The Oriental region was the original home of most of our common domestic animals. The zebu or water buffalo, the elephant, and the zebra are here trained to do useful work. The chicken is a native of this region. Among other birds are the bee-eater, bird of paradise, parrot, pheasant, and tailor bird. The giant python, the cobra, viper, lizard, and the crocodile of the Ganges delta, are among the reptiles. Sumatra, Borneo, and the Philippines are part of the Oriental region, and only a narrow channel of deep water separates this region from one whose animal life is widely different.

6. The Australian Region. — The surface and rainfall conditions of this island help us to understand its strange animal life. It is a plateau so poorly watered that much of the west and center is practically a desert. On the east and southeast the land is well watered and is covered with forests.

In Australia there are animals entirely different from any we have studied. Among the birds are the emu and the cassowary, which are without wings but have developed long powerful legs; also parrots, the laughing jackass, lyre birds, and the cockatoos. There are various kinds of kangaroos, some living on insects, some on plants, and some on flesh, as their surroundings demand. They vary in size from the giant kangaroo to the very small kangaroo rat, and they are called marsupials (little pouch) because they carry their helpless young in a fold of skin on the under side of the body. Their long muscular tail aids them to hop on their hind legs. The duck-billed platypus or mole lays eggs, although it is classed among the mammals.

On account of the sinking of the land and the water barrier thus developed, the fiercer animals of southern Asia and the East Indies have not been able to reach Australia, so that the defenceless animals of this continent, which really belong to a past age of the planet's history, still survive. The Australian region includes also Tasmania, New Zealand, and the neighboring islands, on all of which the animal life is about the same.

Domestic Animals. — Man domesticates animals by changing them from their natural wild state to a condition where they can be trained to give useful service. Climatic control often prevents the spread of domesticated animals over the earth, so that, for example,

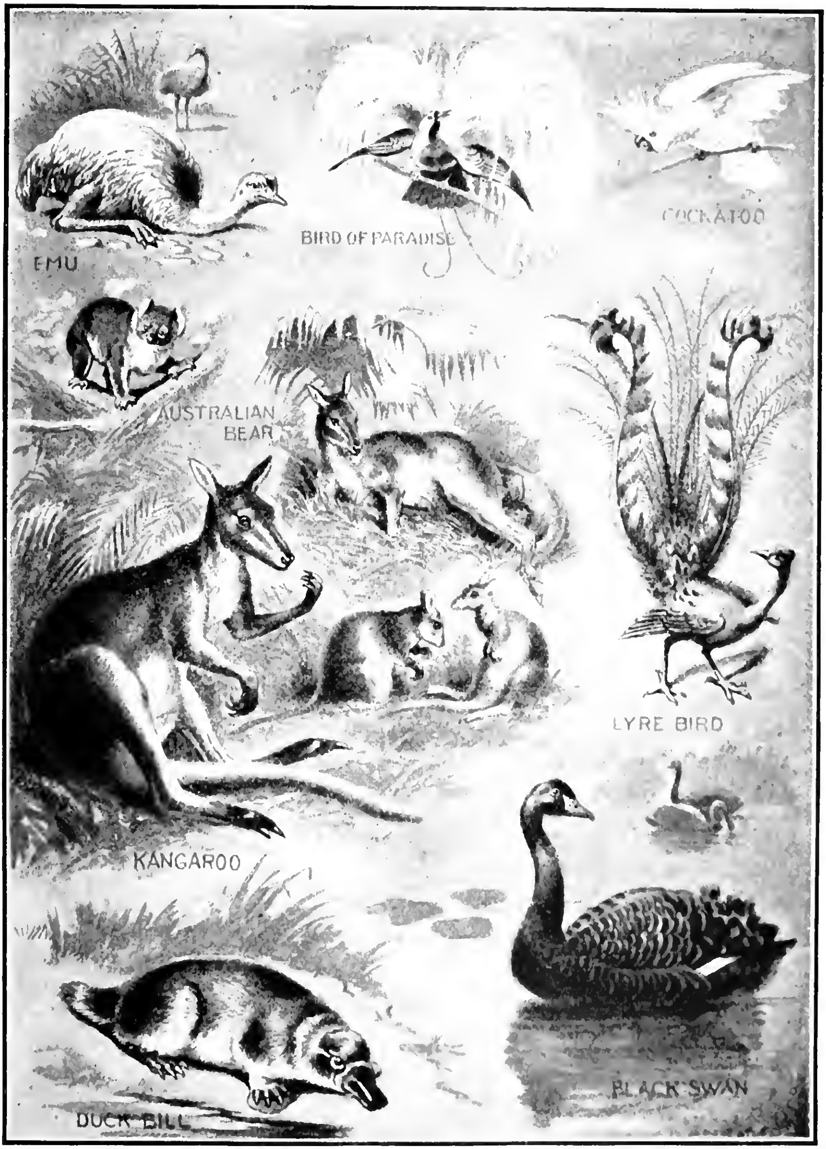


FIG. 155. Some animals of the Australian region.

the Asiatic yak cannot be used in Africa. Many animals, like the horse, the sheep, the dog, the cat, the hen, the goat, the cow, and the pig, have been able to adapt themselves to climatic conditions all around the world as thoroughly as man himself. All, however, need the food and the shelter provided by man.

Life in the Sea. — Marine animals depend directly or indirectly for food upon the vegetation which flourishes in the sea or the food material brought by rivers from the land. Life in the sea is most abundant in the shallow waters of the continental shelf. Owing to their great area and depth, the oceans support more animal life than the land. Among the higher land animals some live in the water, though they are not water-breathers. Among the birds, the penguins swim under water in pursuit of fish. The whale, the dolphin, the sea cow, the seal, and the walrus are all warm-blooded animals which cannot live more than a few minutes under water.

QUESTIONS. — (1) Name the barriers which divide the earth into the five animal regions. (2) In what respects does the animal life of the Arctic belt differ from that in the hot belt? (3) How is the camel superior to the horse in the desert? (4) Show how the cat, the tiger, the mole, the antelope, and the frog are adapted by nature to their environment. (5) What effect is produced by man on the flesh and grass eating animals? (6) Which animals of the world could not exist in North America? (7) Why are the animals of Australia so different from other animals of the world? (8) The rabbit, introduced by white men into Australia, has multiplied so rapidly as to become a pest. Why? (9) What South American animals could exist in Africa? (10) What plant and animal life is likely to be found in the newly discovered Antarctica? (11) Name five typical animals of the desert regions, the tropical forests, the tundras, the grasslands. (12) What North American animals have been brought from other countries? (13) Why cannot animals readily migrate over mountains or across deserts? (14) Name the countries in which you can find in its native home the opossum, the camel, the cougar, the giraffe, the antelope, the armadillo, the emu, the condor, and the musk ox. (15) Show the importance of the following features to each of these animals: the scales and tail of a fish; the neck of the giraffe; the trunk of the elephant; the stripes of the tiger and zebra; the shell of the clam; the coloring of fish. (16) What other examples of this principle do you note in the illustrations of this chapter?

CHAPTER XVI

THE EFFECTS OF CLIMATE ON MAN AND HIS ACTIVITIES

The Influence of Climate on Man. — The highest creature over which climate exerts any control is man. But whether in his civilized state or in his condition of savagery, like all other living things he too must have air, food, warmth, and moisture; he too is dependent upon Nature. From southern Asia, which has been called the cradle of the human race, to all the lands over which he has spread, man has been driven to activity to secure the two requisites for existence, — food and shelter. In this quest he is under the bonds of climatic control.

True, of all creatures on the earth man is the one best able to adapt himself; but he cannot exist for any length of time in regions where there is no water, nor plant or animal life. Climate is a more important factor in man's life than the various forms assumed by the earth's crust in its cooling and changing. The influence of climate is greater than that of ocean, mountain, desert, river, volcano, prairie, and jungle. Climate determines where man shall not live, how he shall live in those lands which he does inhabit, and largely to what degree of civilization he shall advance.

Fig. 156. Laplanders.

Man in the Climatic Zones. — As we should expect, regions of permanent ice around the poles and on mountains are uninhabited. We have seen that agriculture in the Arctic belt is impossible. The

few animals there can support only a sparse population. Here live the Eskimos. Being forced to depend on animals alone, they use their flesh for food, their skins for clothing and summer tents, and their bones for spears and for the framework of their kayaks or boats. All the energy of people in these polar regions is directed to securing

Fig. 157. An Indian camp in Canada.

food and shelter, and little opportunity is afforded for their development and better civilization, so that they remain savages dwarfed in body and in intelligence (*Figure 149*).

In the torrid zone conditions are quite the opposite to those in the Arctic. The plant and animal life supply an abundance of food ready to the hand of man. He has little need for shelter or clothing. Practically no effort is required on his part to obtain and prepare the necessities of life. Indeed, the rains, heat, and dampness prevent the carrying on of any steady work. As a result, the natives of this zone have emerged scarcely above the state of animals. They are indolent, unintelligent, and without ambition. They comprise the negroes of Africa, the natives of Australia and the Philippines, and the Indians of Central America and South America.

In these two zones climate is an inflexible taskmaster. So cold and so barren are the Arctic lands, so enervating the torrid climes, that the natives have to live from hand to mouth. Division of labor is unknown among them. Each family gets or makes what it needs

for its own members. They hunt and fish or gather edible roots or the fruits of plants about them. The men are the hunters and fighters, the women prepare the food and carry the burdens. Their homes meet the demands of climate; they keep out the icy wind, lift the family above the equatorial dampness, or shield the members from the sun. These hunting and fishing races need a large area to furnish the food necessary for only a few people, so that their tribal or village groups are small, comprising only a few families. They have no fixed abode, but the groups move about the country after the game or as they wish. Their weapons and implements are of the simplest kind.

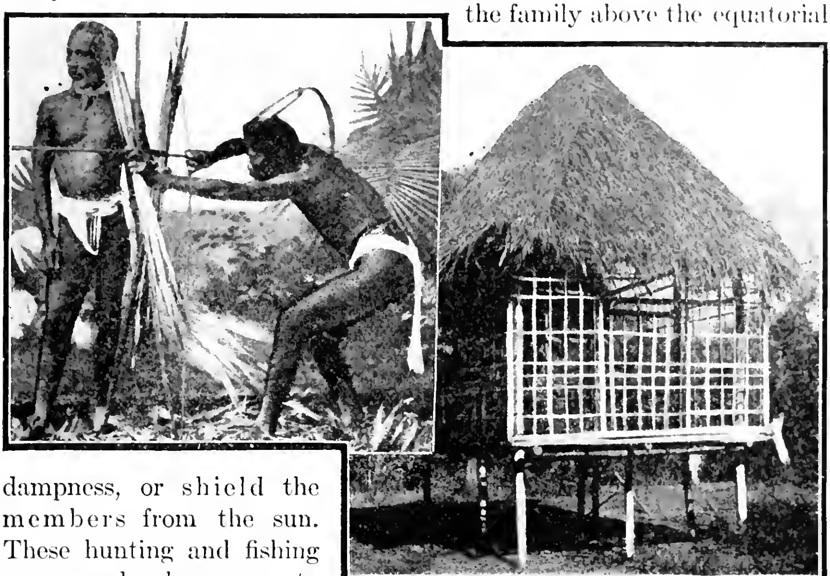


FIG. 158. Savages in the interior of the Philippines and their home in course of construction.

The Temperate Zones. — In these regions we find the happy medium between the two extreme effects of climate. Here the winters are not too cold nor the summers too warm. In our study of plant and animal life we found that nature here gives to man, but not with a lavish hand. In this belt the most useful plants grow and the domesticated animals can increase. Man must put forth some effort to secure what he needs. He must learn to be prudent and watchful to meet the climatic changes: he must store food in summer to eat in

winter. To provide food and to secure shelter he must spend his energies with intelligence and foresight. In this belt, in the middle latitudes of North America, Europe, and eastern Asia, we shall find the most progressive and most highly **civilized** people of the world.

We must not expect the human race to be evenly distributed over the temperate zones. This could happen only if there were no other conditions than those of climate. Of course, man will find the great coastal plains, where the climate permits outdoor life all the year round and where there is abundant moisture, more favorable for his home than the tops of inland plateaus. Mature, level valleys, flood plains, and broad, fertile deltas will shelter the greatest number of

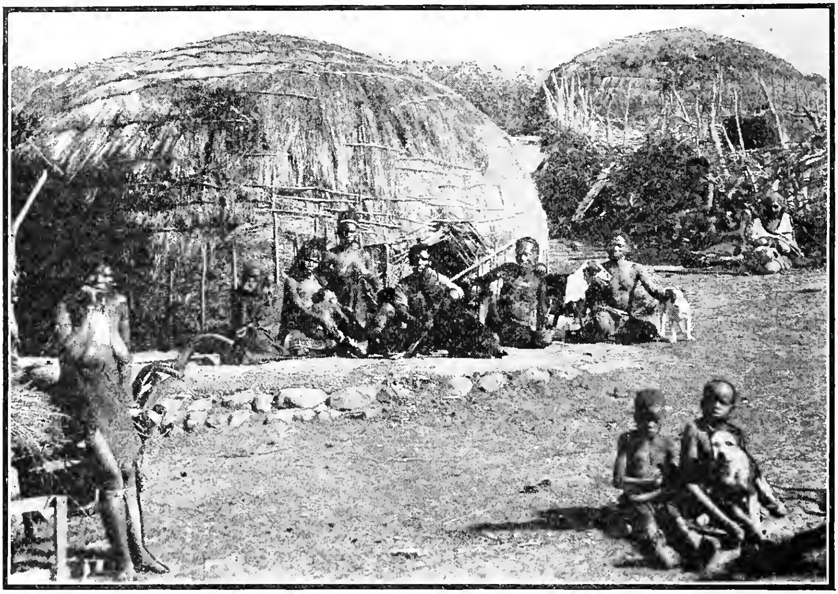


Fig. 159. Homes in a Kafir village.

people. Note, for example, the population at the lower end of the Nile (*Figure 163*).

Man in Desert Regions. — There is a condition of life in which climate forces man to live, that is midway between the savage and the civilized states. People in this state, types of whom are the

Arabs of Asia and Africa, the tribes of Siberia and Tartary, the Pueblo Indians, and the Aztecs of Mexico, either carry on grazing and follow their herds and flocks as the seasons change, or raise scanty crops from the barren soil in a primitive way. They are called **barbarians.** The wandering barbarians or **nomads** who live largely on

FIG. 160. Indian rubber gatherers and their homes along the Amazon river.

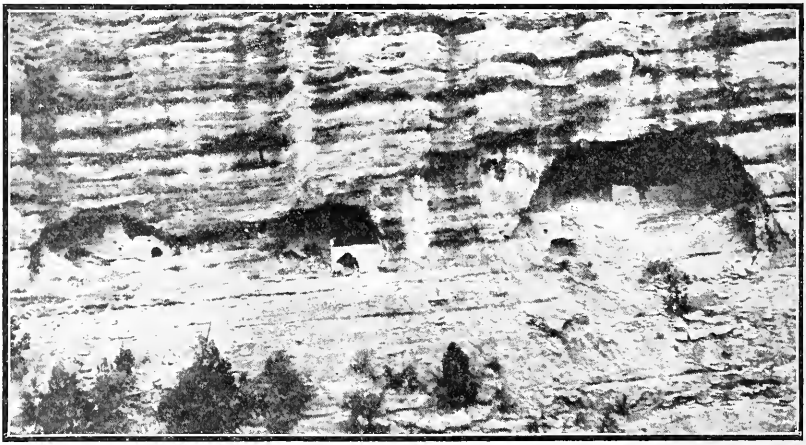
the sandy deserts are made intelligent, hardy, and daring by their constant struggle for existence. They have domesticated their animals and developed simple industries; but there is little division of labor or community life, each tribe and family looking after its own needs. Then the desert barrier prevents these people from learning from the people of other and more favored regions.

Races of Mankind. — Despite the many differences among men in race and color, in modes of life and in religion, all are believed to have come from a common stock. The influences of different climatic conditions, determining the nature of the foods and the modes of life, are supposed to have brought about the wide racial variations. On account of these differences, we usually divide mankind into five great classes or races.

The White or Caucasian Race is the highest type. Its members have advanced farthest in civilization; they are the great discoverers, inventors, and manufacturers. They have migrated most extensively, driving out and supplanting weaker races. The American Indians were driven from the Atlantic to the West by the European

whites. To-day, whatever development is taking place in the torrid zone is being accomplished by members of the white race. The white race comprises many nations speaking many tongues; in New York City there live thirty-five different nationalities, each speaking a language of its own. The activity and enterprise of the white race have placed the white man foremost in North and South America, Europe, and along the coast of Australia, and in all the tropical countries.

Among the peoples of the Caucasian race, there are three well-marked types. The **Baltic type** is blond or florid, with reddish hair, blue eyes, and tall stature. It includes Scandinavians, Germans,



Am. Mus. Nat. Hist.

FIG. 161. The homes of cliff dwellers in Arizona.

English, Scotch, and Irish, West Persians, and Hindus. The **Alpine type,** with light brown complexion and hair, brown, gray, or black eyes, broad skull, and medium stature, includes the French, Welsh, South Germans, Swiss, Russians, Poles, Bohemians, East Persians, and Armenians. The **Mediterranean type,** with olive brown to black skin, black hair and eyes, and small stature, includes the Spanish, Portuguese, some French, Welsh, and Irish, Italians and Greeks, Egyptians, Arabs, Syrians, and some Hindus.

The Yellow or Mongolian Race inhabits all of Asia not occupied by the Caucasians. The **Chinese branch** includes the people of

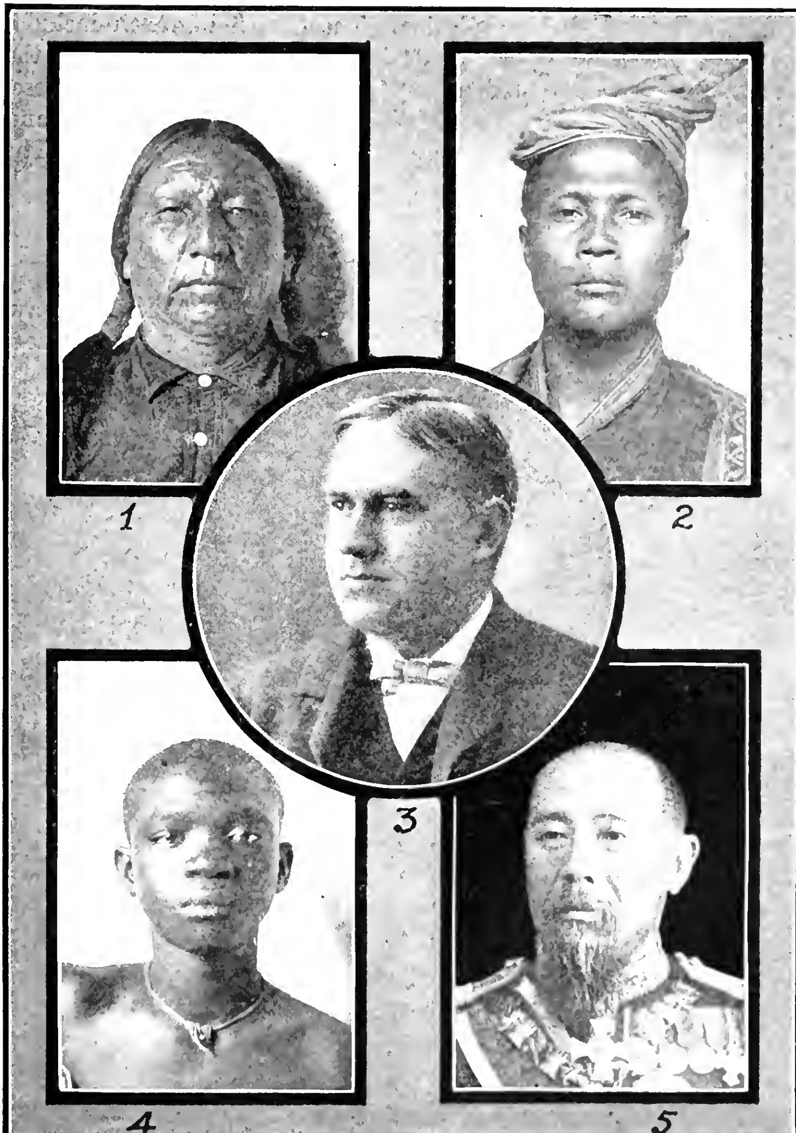


FIG. 162. The Five Races of Mankind. 1. The Red. 2. The Malay or Brown. 3. The White or Caucasian. 4. The Black. 5. The Yellow.

China, Tibet, Siam, and Indo-China. The **Siberian branch** includes the Manchus who conquered China in the seventeenth century, the Turks, the Cossacks, the Eskimos, the Finns, the Lapps, the Japanese, and the Koreans. Dwarfed stature among the Eskimos, Finns, and Lapps has resulted from the severe cold and the long polar night. The Mongolians are characterized by their coarse, straight hair, small noses, and the oblique appearance of the eyes. They cling tenaciously to old customs, but the influence of the white race seems to be arousing them. The Japanese is the most active and progressive nation of this race, and its members are called the Yankees of the East, having by deliberate adoption added to their native civilization the most advanced ideas of the Caucasians.

The Brown or Malay Race consists of the dark-skinned people of the Malay Peninsula and the Straits settlements, including the Philippines, Java, Sumatra, New Zealand, and New Guinea. The members are small in stature and low in order of civilization.

The Black Race occupies all the tropical regions of the continents of Africa and Australia and many of the Pacific island chains. It is thought that the dark skin of this race is due to Nature's efforts to protect man from the heat and moisture of the tropics. The inhabitants of all warm countries tend to become dark-skinned. Take the Hindus, for instance, who, except for their dark skin, have no other feature in common with the negro race and are classed with the white stock.

The control of climate is seen clearly in the indolent unprogressiveness of the members of the black race. They are a people fitted carefully by nature for life in the hot belt. The race includes among others an unusual variety of small men about four feet in height, their stature due to lack of sunlight, known as the Pygmies, who inhabit the forests north of the Kongo. The yellow and the black races have seldom migrated from their native homes. The negroes who have gone to other lands have mostly been carried as slaves to the western hemisphere. They are scattered to-day very widely through Brazil, West Indies, Peru, United States, and Mexico.

The American or Red Race includes all the native inhabitants of the western hemisphere. Since the characteristics of this people, the reddish-brown skin, small eyes, and straight black hair, are so

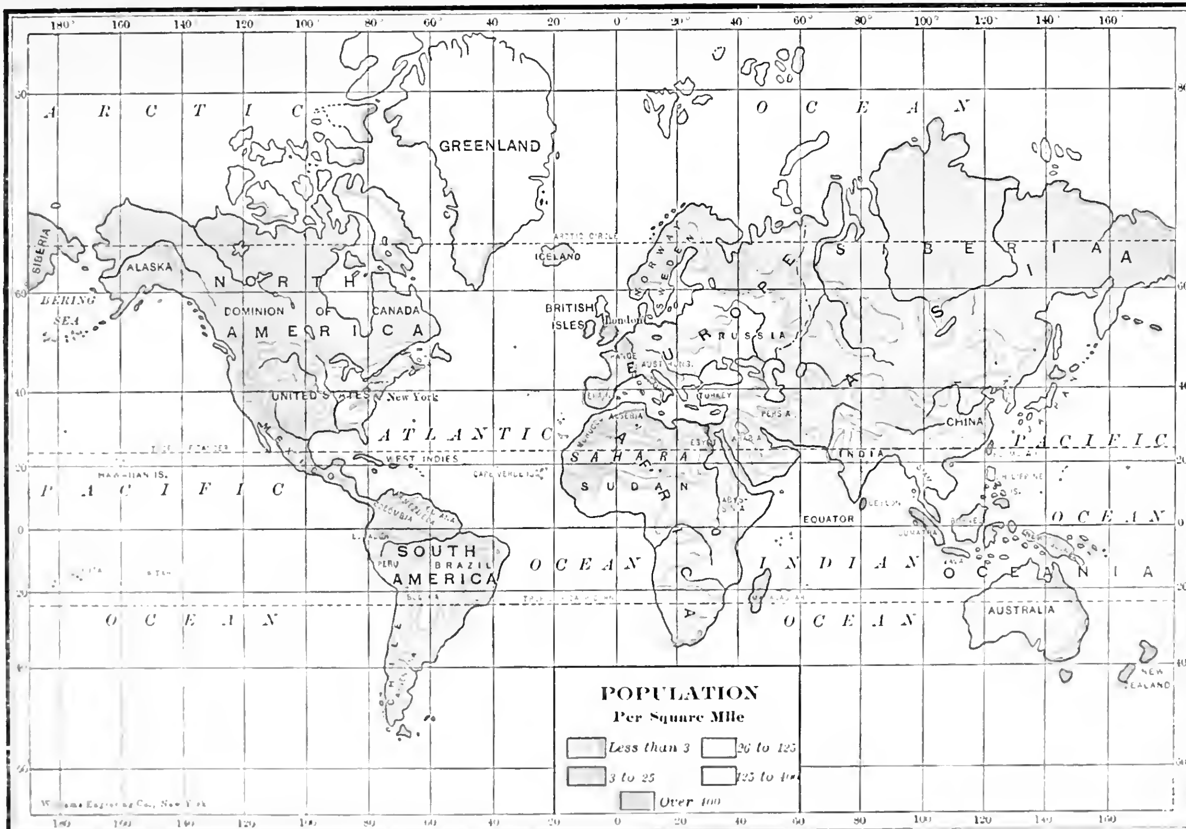


FIG. 163. A map showing the density of population of the world.

similar to those of the yellow race, we believe that the North American Indian may have been of Asiatic origin. Weapons and relics are sometimes found which seem to strengthen this suggestion that tribes crossed over Bering strait. This race includes all the various tribes once the inhabitants of our country from ocean to ocean, the Pueblos and the Cliff-dwellers, the Aztecs and the other tribes of South America and the West Indies, and the rude Patagonians and Fuegians. For centuries they have given way before the white race, and only those members are surviving who are adopting the ways of their conquerors.

The Population of the World. — The total number of inhabitants of the world spread over the earth, as shown in *Figure 163*, exceeds 1,650 millions. The white or Caucasian race makes up 52 per cent of this number, the yellow and brown races 36 per cent, the black race 11 per cent, and the red race 1 per cent. We can see also that the large groups of dense population are all in the northern hemisphere, and mostly between the tropic of Cancer and the Arctic circle. About 80 per cent of the world's people live between the annual isotherms of 40° and 70°. We have already learned why this climate favors the denser population.

In any region the population will always depend upon the facilities for obtaining food. We may look for heavy populations in warm lowlands without excessive rainfall; for example, in southeastern Asia, where one half the people of the world raise their own food products. On the other hand, cooler and drier lands will support heavy populations if abundant and unfailing supplies of food from other countries can readily be brought in by sea or by rail. In western Europe, one fifth of the world's people subsist largely by buying food from Asia, eastern Europe, and America.

Effects of Climate on Man's Activities. — The climate of a region generally determines the industries which may thrive there. Lumbering, and the production of turpentine, tan bark, and rubber can thrive only where there is sufficient rainfall to maintain forests. Climate determines what kinds of crops shall be raised, whether corn, for example, or wheat, rice, sugar cane, coffee, alfalfa, tobacco, or cotton, etc. Stock raising is also controlled by climatic conditions. Graz-

ing and herding can be conducted profitably only where grass will grow abundantly. Farmers in our North and South Atlantic states, in England, Germany, and India, raise cattle in a small way; but with herds of thousands of cattle, goats, sheep, and horses, the stock-raising industry is carried on best in regions too dry for ordinary farming. These are the semi-arid plains, steppes, llanos, and pampas of Russia,

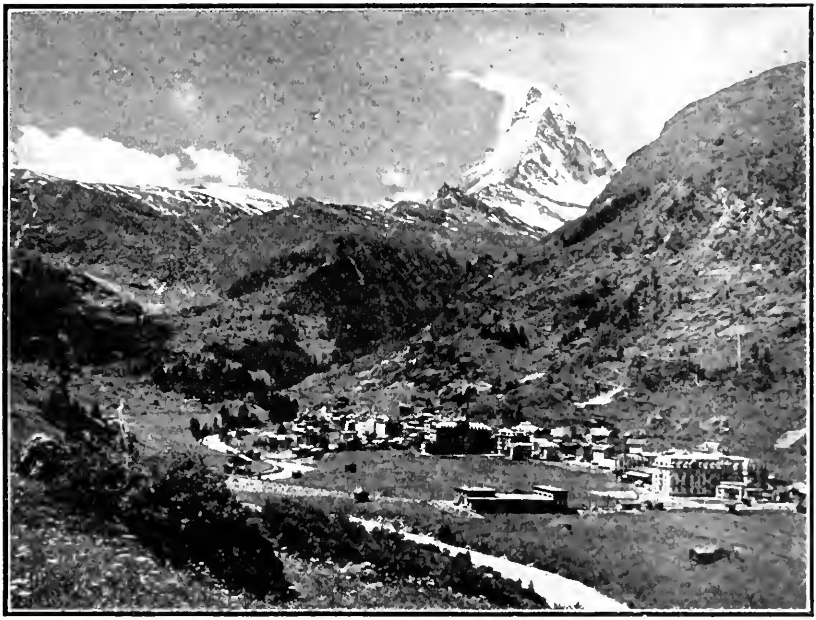


FIG. 164. How man seeks the shelter of a protected valley for his home.

South Africa, Argentina, Spain, Australia, Mexico, and the Great Plains of our West.

If man engages in manufacturing, he is checked again by climate, because he must have all the raw materials which can be provided only by the industries mentioned before. The success of the wheat, sugar, cotton, and tobacco crops concern the great milling establishments, the sugar refineries, the textile mills, and the cigar factories. We have seen the effect of weather changes on certain manufactures.

There are other industries, such as salt evaporating and open-air fruit drying, which depend upon dry climate conditions.

Effects of Climate on Commerce. — Among savage peoples, every man seeks only the necessaries of life for his own family, without help from others. In his civilized state man follows many varied industries, and there is a division of labor. This means that each worker gives most of his time to one industry, and later exchanges the product he cannot use himself for other things that he needs which are produced by other men. We have seen how climate determines man's needs and what he can produce. England cannot produce the enormous amount of wheat and sugar she consumes, so she has to rely on the wheat and sugar producing countries for these commodities. In this way there is a great division of labor among nations also, and an interdependence of one region upon another. In the same way, the various classes of people in a region depend one upon the other, while all are dependent upon the farmer who takes the world's food from the soil.

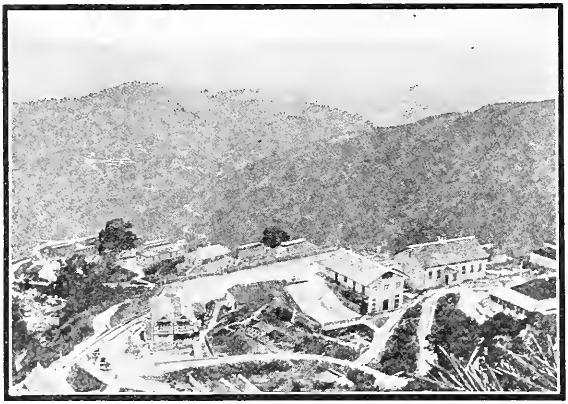


Fig. 165. How man in the tropics seeks a home on a mountain to avoid the heat of the lowlands.

Not only does climate determine what commodities shall be exported or imported by nations, but it influences largely the methods and the facilities of transport. Climate both permitted and compelled Great Britain to become a great commercial nation. For, while she is favored with a climate mild enough not to block her ports with winter ice, she has to fight against and master the seas from over which her ships bring the supplies for food and manufactures.

The location of railways, bridges, grain elevators, factories, and wireless stations is normally controlled by temperature, wind, moisture, and other climatic elements. Railroad communication is ob-

structed by snow in Canada, Scotland, and our western states; in the deserts by the effects of wind-driven sand; and in the moister part of the tropics the luxuriant vegetation greatly handicaps the construction of new lines.

Other Effects of Climate on Man. — Climate affects the life of man in many minor ways. It generally determines what kind of shelter he must rear to house himself in. The Eskimo finds his igloo warm and comfortable in the winter, but the summer drives him to his skin tupic. The native of the tropical forest makes his hut of bamboo, palm, and cocoanut leaves, sugar-cane, and grass. In the rainy season he is forced to erect structures in the trees or on piles. In the tropical deserts the dwellings are of stone with flat rocks on which the people sleep at night. In continental countries the walls of houses are commonly built thicker than in maritime countries, in order to check the entrance of extreme heat and cold. In Canada double windows are used. In southern Europe carpets are rare, bare stone or wooden floors being used as a protection against the summer heat. In the Mediterranean countries the houses are generally white in color to reflect the sun's heat.

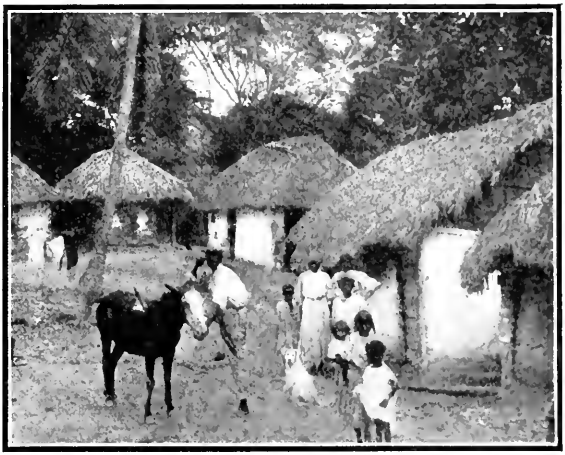


FIG. 166. A group of native huts in Jamaica.

In cold climates man needs more heat-producing foods, like fat, oil, and sugar, than in warmer climes. The Eskimo lives entirely on animal food; while in the tropics the diet of the natives consists of vegetable products, such as the banana, cocoanut, breadfruit, rice, yams, sago, and, in the desert oases, the date. The nations of the temperate zones require a diet of mixed animal and vegetable food.

Climate affects the dress and clothing of man and his modes of

locomotion. The Eskimos traverse the frozen snow in dog or reindeer sledge, while equatorial natives move about the flooded country so much in boats that certain tribes scarcely know how to walk. Besides temperature, humidity, wind and sunshine, there is another element of climate which influences very widely the habits of people with respect to indoor and outdoor life, and that is the varying length of the day in summer and winter in the different latitudes. In low latitudes, between 45° north and south of the equator for example, the great contrast between the length of the day in June and December that is so remarkable in higher latitudes is missing. The habits of people in low latitudes will therefore vary comparatively little with the seasons, while people living farther north and south will spend a great part of the summer in the open air but will be forced to live indoors during the colder periods. Moreover, climate determines man's sports and national games. In Canada, except on the Pacific coast, the winter is the gay season of merriment. Skating is enjoyed in the more eastern countries of Europe, curling in Scotland, and skiing in Norway. Switzerland, on account of the longer days, however, is the winter playground of Europe rather than Norway. In Colorado, tennis and skating are enjoyed at the same time in the dry and bright frosty conditions.

QUESTIONS. — (1) What zones are most favorable to the physical and mental development of man and for what reasons? (2) Upon what conditions are all men dependent? (3) Why do not the Eskimos advance? (4) What conditions in the tropical zone are unfavorable to civilization? What is the condition of the native inhabitants? (5) How does the life of a savage differ from that of a barbarian? Where may types of these people be met with to-day? (6) Why are so few members of the brown race seen in New York? (7) What is an important cause of the differences among men? How does civilized man differ from the other types? (8) Give reasons for the spread and success of the Caucasian race. (9) What characteristics are we likely to find among mountaineers? (10) How are the members of the black race fitted to their native environment? (11) In what ways are Indians adopting the customs of the white race? (12) Why do men live near rivers? (13) Upon what does the population of any region depend? (14) What climatic conditions are favorable to the advance of the United States? (15) Why do men gather in great cities? (16) Show how climate affects the houses, clothing, and habits of man. (17) How does climate affect the education of a native boy on the Amazon, a Kafir boy, a Chinese boy, an Eskimo boy? (18) On *Figure 163* account for the population of Australia. (19) Why are the densely populated areas of South America all near the coast? (20) How is Bolivia dependent on Argentina? Why does Europe depend on Russia? Why is Siberia bound to grow in importance? (21) How does England depend on North America? How does New York depend on the West? How does the West depend on New York?

EXERCISES. — (1) Make a drawing of a favorable and an unfavorable coast line. Tell the effect of a coast line on the development of a country. (2) Find instances on *Figure 163* where mountain, desert, and water barriers restrict population to certain regions. Name these barriers. (3) Write statements showing how the climate of Cuba, Iceland, Siberia, Brazil, Alberta, Mexico, and Argentina affects the life of the inhabitants of each. (4) What other causes besides climate affect the occupations of the people of a region? Consider New England, Nova Scotia, Germany, Japan, and England. (5) Make a list of the divisions of the human race, and tell where each is found. (6) Describe the features and characteristics as you have observed them of the yellow, black, and red races. (7) Make a list of ten occupations practiced in New York, and tell how the workers depend one upon the other. (8) On an outline map of the western hemisphere darken the most densely populated regions. Account for this population. (9) Make a list of all the nationalities of the Caucasian race in New York, and classify them under the three types. (10) Show how the industries of the United States are determined by the climate. (11) What facts account for the importance of the British nation?

CHAPTER XVII

HOW MAN CONQUERS HIS ENVIRONMENT

The plant, the animal, and the savage accept the conditions of their surroundings placidly or die off after struggling vainly against an unfavorable environment. Civilized man alone, and especially of the races living in the north and the south temperate belts, attempts to change his environment, to make it more favorable, and to adapt it to his needs. For these reasons, man changes the surface of the earth, he outwits the tricky changes of the weather, and fights to overcome the effects of climate; he is tireless in his conquest of the forces of the sea, and he attempts the mastery of the air.

Man and the Earth's Surface. — The efforts of millions of men are continually directed to making the earth a better home. Where man needs land that is covered by a swamp, the water is drained off, the land filled in, vegetation is introduced, and soon, as in Florida, oranges or other useful products grow. One twentieth of the surface of Europe has been drained in this way, and it is still possible in the United States to drain 78 million acres, which is now swamp land. Where sand dunes encroach upon his homes near the shore, he plants trees and shrubs to check their advance. He tears out the heart of mountains for their minerals, and blows off the face of great cliffs and palisades.

When rivers and lakes interfere with man's development, he undertakes to check their natural course. In every continent he has dammed streams to make reservoirs to store water for his use. The Ashokan dam system can supply 770 million gallons per day to New York City. When old rivers, like the Mississippi, overflow their flood plains, he builds levees along the banks to confine the waters. To build the Panama canal, the Chagres river was turned out of its course; in Wyoming, a river was diverted into a valley to make a lake. In the Sahara, man tries to overcome the desert by drawing up water through artesian wells.

Man brings the plants and animals of one region into another to help supply his needs. The Angora goat, the camel, and the ostrich are thriving in our West. He even imports one animal or plant to live upon and thus kill off another harmful species. Often he makes no improvement on Nature; for example, we have vast areas in the

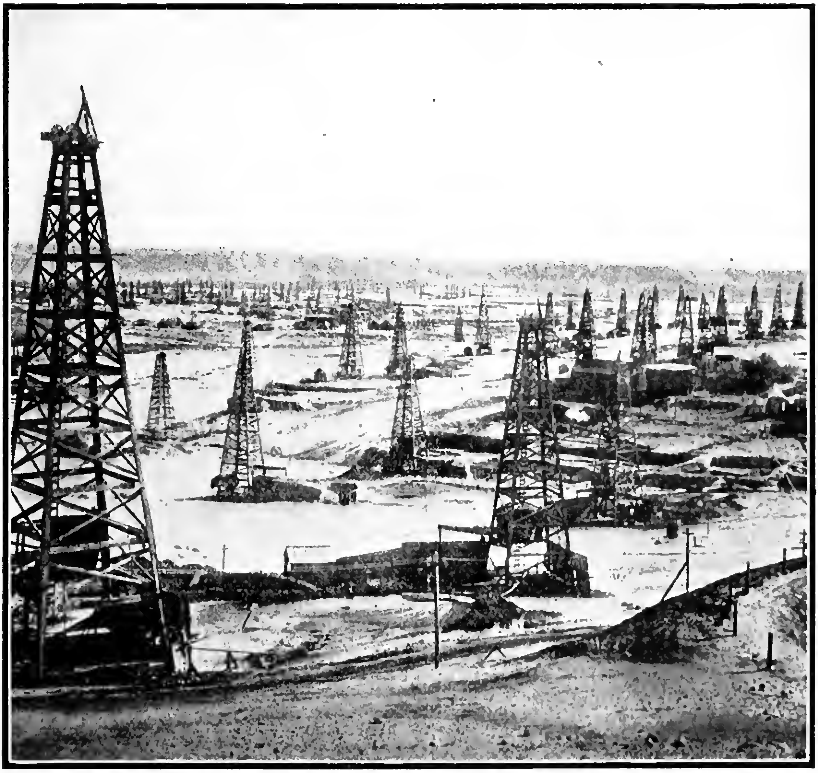


FIG. 167. Oil wells in a California oil region.

United States which have been deforested to furnish lumber. Great, bare, arid scars are left in this way. Germany and France, on the other hand, are changing the earth's appearance by planting every year hundreds of thousands of trees.

Man drives deep wells into the earth for water, gas, and oil, and

thus brings these substances to the surface for his use. In his search for coal, iron, copper, and other mineral products, the strata are wrenched and blasted, and honeycombed with shafts and tunnels. In quarrying and mining, great gaps are dug in the surface at one place, and huge hills of waste materials built up at others.

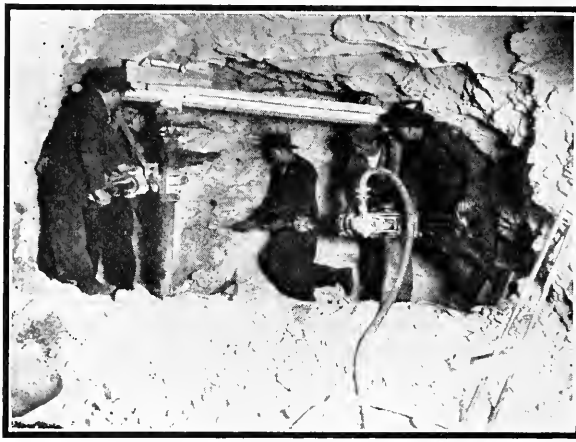


Fig. 168. Cutting a railroad tunnel through the Alps.

Where a harbor is needed, man with his giant dredges deepens a waterway or blows out great rocks and shoals. When a hill is in the way of some improvement, it is removed; when land in great cities is densely populated and is therefore very valuable, man builds huge structures for himself to work in or live, calling them skyscrapers.

Communication and Transportation. — Savage tribes have little communication with one another. Civilized man in the spirit of helpfulness, which is his great characteristic, would make the whole world one huge family. Nothing has spurred him on so much to change the earth's features as this desire to surmount all barriers of time and space between groups of men.

Roads extend like countless ribbons everywhere over the inhabited globe, and 700,000 miles of railways cross its surface. Where mountains interrupt their progress, man overcomes the barriers by wonderful railway tunnels like the mount Cenis, the Simplon, and the St. Gothard tunnels in the Alps, the second over twelve miles long. The Himalayas, the Andes, and the Rockies have all been pierced to save time and promote communication. Eight transcontinental railroad lines cross North America; and there is one connecting Vladivostok with St. Petersburg. We are likely to see a pan-American line from

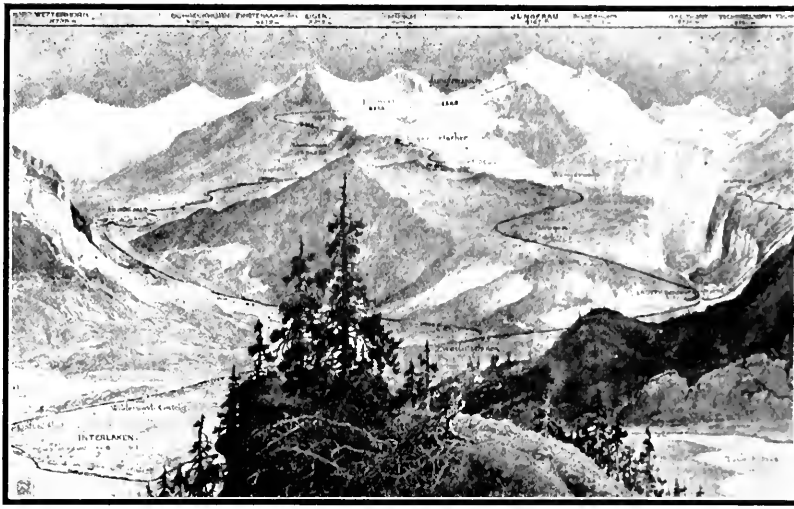


FIG. 169. Swiss railroad lines surmounting all the difficulties of the mountainous regions.

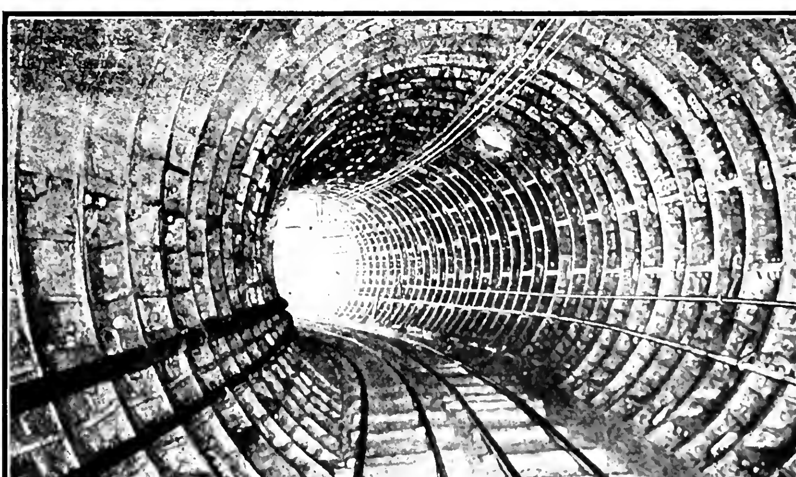


FIG. 170. A tunnel under the Hudson river at New York.

Canada to Argentina; and a Cape-to-Cairo line in Africa will be in operation shortly. The Hudson river tunnels in New York were one of the most difficult of engineering feats; but now a tunnel under the English channel is contemplated, and another under Bering strait is proposed. The Oroya railroad in Peru, the highest in the world, is a marvel of engineering skill, ascending to a height of 15,650 feet. The Jungfraujoch station of the Jungfrau railroad in Switzerland is the highest station in Europe, situated 11,400 feet above the sea. In our West the tracks of the transcontinental roads creep up steep mountain sides in loops, and bridge canyons, chasms, and torrents. Great suspension and cantilever railway bridges, like the one at Niagara Falls and the Tay bridge in Scotland, 11,000 feet long, carry man over rivers. Transportation in a great city shows man's mastery of the earth. In New York he rides in the air, on the level surface, and under earth and river. The Hell Gate bridge over the East river in New York will be three miles in length and will bear four railroad lines.

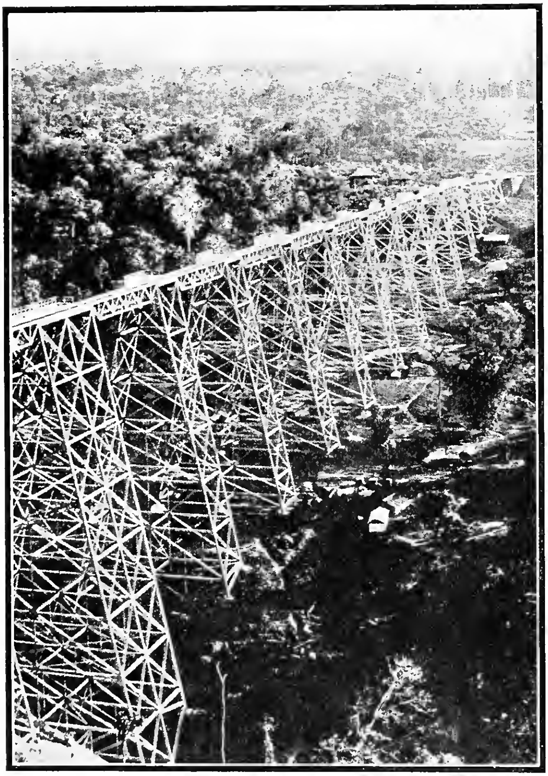


Fig. 171. The Gokteik viaduct in Burma.

The telephone and the telegraph keep the most isolated parts of the earth in touch with the busy centers, and ships at sea are always

in communication with land through wireless telegraphy. A message encircles the earth in twelve minutes. The number of messages transmitted annually over the 1,750 submarine cables of the world is over eight million.

Giant dredges fight constantly against the shifting currents of rivers like the Nile, the Mississippi, and the Missouri, that choke up their channels with sand. These machines draw up enormous amounts of mud and gravel to be carried away in scows, so as to permit man's

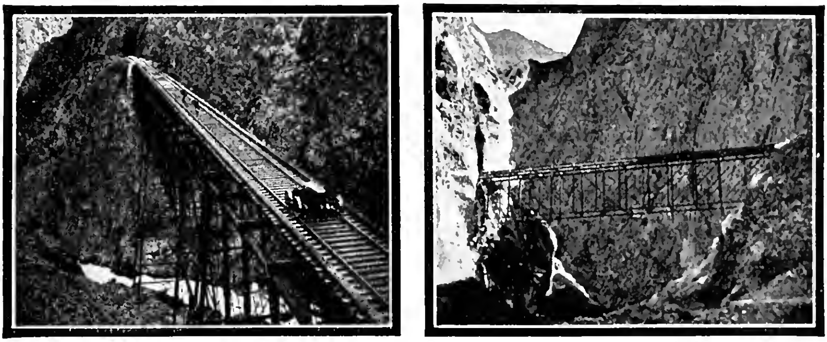


FIG. 172. Scenes on the Oroya railroad in the Andes.

ships to pass unhindered. The mud and gravel are dumped on shore, thus increasing the acreage.

Pipe lines filled with petroleum run like great arteries across the Middle and South Atlantic states, Texas, California, Germany, and Russia, to supply the 300 million barrels of oil man every year changes into light, heat, and power. In many places there are pipe lines to convey natural gas to distant points.

Perhaps in no greater way has man shown his power than by constructing canals to connect the waters of different oceans. Just as the discovery of gold in California led to the construction of the Panama railroad, completed in 1855, so the constant desire of restless man to avoid the waste of time and the expense of the trip around cape Horn led him to build the Panama canal. Before the opening, a ship steamed 15,000 miles from New York to San Francisco. Through the canal the voyage is 5,000 miles. In like manner a shipper saves 8,000 miles from New York to Yokohama and 5,000 miles to Val-

paraiso; 8,000 miles are saved in steaming from San Francisco to Liverpool, and 6,500 miles to Genoa. This supreme work of man cost 400 million dollars, and also cost many men their lives; but its effects in aiding mankind more completely to conquer the earth will be very great.

There are thousands of smaller canals. In Holland, they are more common than roads. In the Manchester canal in England, a cotton steamer from New Orleans can pass along its thirty-five miles in three hours and unload its cargo at the doors of the cotton mills. Five thousand vessels a year pass through the Suez canal. Germany, Canada, China, and the United States have many canals. The Antwerp and Liége canal will be 84 miles in length, and the Danube and Adriatic canal 319 miles long. Note on the map the effects these new canals will have on Europe.

Man and the Ocean. — The conflict between man and the sea is never ending. Year by year the ocean becomes less of a hindrance to his progress. A ship may be thought of as a tiny bit of land moving from one region and floating across the water to attach itself to an-

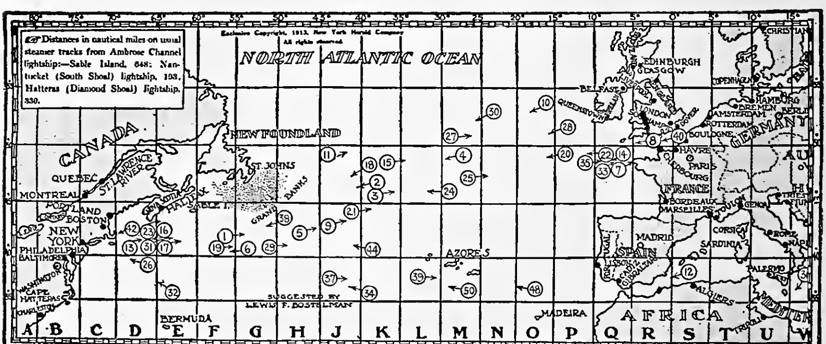


FIG. 173. A newspaper chart published to show the daily position of steamers at sea.

other region. Man strives constantly to make the size of this bit larger and to make its trip more speedy. The Atlantic is crossed in five days by 1,000-foot steamers displacing 50,000 tons, carrying 3,800 people, and burning daily 1,200 tons of coal. Every day 1,000 ships enter or leave the ports of Great Britain. A bushel of wheat is carried

from North Dakota to Liverpool for fifteen cents; lumber is carried at a profit from Oregon to China and Cape Colony. A steamer crosses the Pacific to Hongkong in twelve days. Note in *Figure 173* the number of transatlantic liners carrying the people and products of Europe to America or *vice versa.*

All governments unite in the endeavor to render safe the passage of ships over the seas. Charts of every coast showing lighthouses,

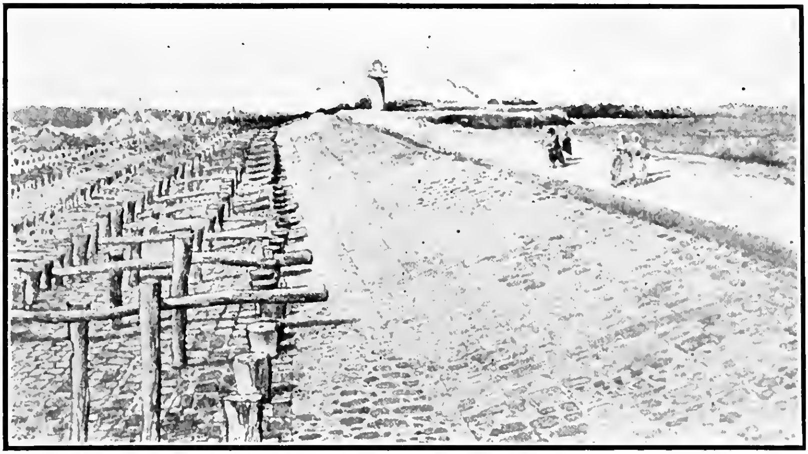


FIG. 174. One of the great Holland dikes at low tide.

buoys, reefs, and shoals are issued. Vessels are warned of weather changes and the action of currents, and of the position of icebergs and derelicts. *Figure 173,* a chart published by a daily paper, is an example of the watchfulness maintained over passenger vessels at sea. The actions of tides are carefully measured and charted for the benefit of vessels entering and leaving port.

To satisfy his needs, not only does man strive to surmount the ocean barrier, but he constantly wrests more land from the sea. He pushes out great piers into its waters to supply shipping facilities, for amusement purposes, or because no suitable landing place is available. He builds great breakwaters, as at Rio de Janeiro, Calcutta, Hongkong, Liverpool, and Seattle, to make harbors safer, or he deepens the mouths of channels and estuaries to permit his huge liners to enter

the harbors. Inventors are even trying to harness the force of the waves by means of a wave-motor which shall use the ceaseless action of the water to supply power for electric dynamos.

"God made the sea, but the Dutch made the land." In Holland, the dikes keep out the sea from 50,000 acres of reclaimed land. The Dutch engineers are now busy with a project to reclaim from the

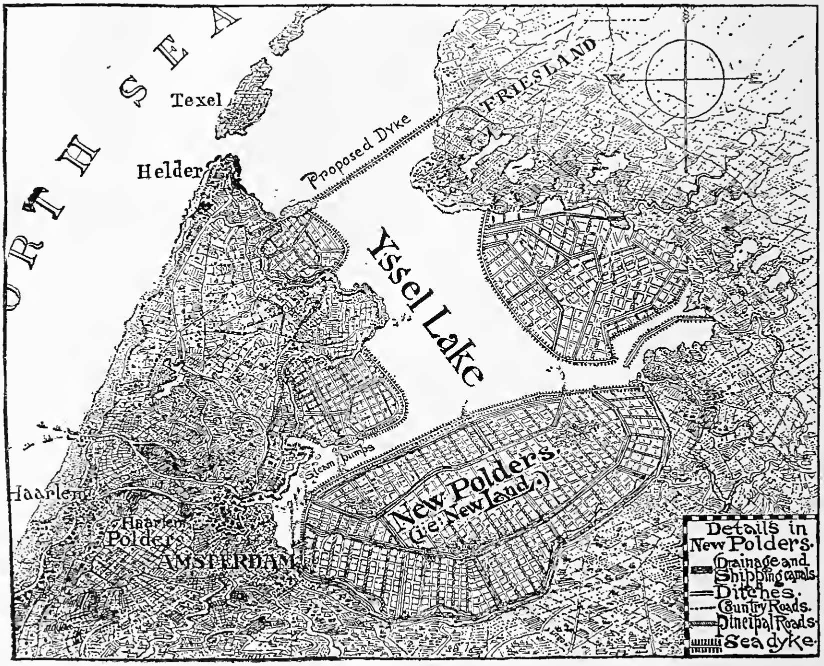


FIG. 175. How the Dutch are planning to wrest a great body of land from the North Sea.

ocean the enormous bottom of the Zuyder Zee, by building great dikes and then pumping out the water. This district, larger than the state of Texas and sufficient to maintain three million people, will add 500,000 acres to their territory. Land has been wrested from the sea in many seaports like London, Boston, and New York by filling in the shallow waters.

The Conquest of the Air. — The minds of men are busy with the conquest of the atmosphere. Already balloons in Germany carry freight and passengers on schedule time. In 1912, in France, 1,600 new machines were built for navigating the air and 12,000 passengers were carried. There is no important nation that does not include the monoplane, biplane, and dirigible balloon in its military and its naval equipment. In the Italian-Turkish and Greek-Turkish war aeroplanes proved of valuable service. Experiments are being made for the more rapid delivery of ships' mails through the use of aeroplanes when the vessels near port. One by one man is learning the secrets of air currents and wind pressure above the earth. Hitherto attempts to cross the Atlantic by means of air fliers have failed, but man's inventive genius and daring will yet find a way to do this.

FIG. 176. An aeroplane passing over the Alps at a height of 13,000 feet.

The Conquest of Climate. — Man cannot change climate, but he strives constantly to modify its effects. In cold countries he heats his house artificially; in Haidarabad, in India, he appends wind sails to the outside of his house to catch the wind and aid in ventilating the interior. In Australia, an item of furniture is always a canvas bag to cool water by evaporation. Only through his conquest of climate has the white man been able to live in the unhealthful tropical countries. The first step in building the Panama canal was the elimination of yellow fever in the canal zone.

We have seen how closely the spread of man and animals depends on vegetation. Man has been very successful in overcoming the effects of scanty rainfall. In many regions he has done this by hold-

Fig. 177. A California desert before irrigation.

Am. Mus. Nat. Hist.

Fig. 178. A part of the same region under irrigation.

ing back the water that would otherwise run off the land, so as to form large artificial reservoirs, and then feeding it out to the land as

needed. This watering of the land, either with the water thus stored up or with water diverted from rivers or pumped from deep wells, is known as **irrigation.** In Turkestan, India, Italy, and Mexico it has been used from time immemorial.

The results of this work of man are seen everywhere from Patagonia to Alberta, from Spain to Indo-China. Regions that would otherwise be deserts have become fertile garden spots through irrigation. At Assuan, in the middle of Egypt, an enormous dam has been constructed across the Nile, causing a rise of 65 feet in the level. When water is badly needed in lower Egypt for the valuable cotton crop, canals distribute it. The Nile is also dammed at Cairo, Siut, and other places; no other river in the world is so thoroughly under the control of man. In India, where 25 million acres are irrigated, the systems insure regular and larger crops and reduce the danger of famine.

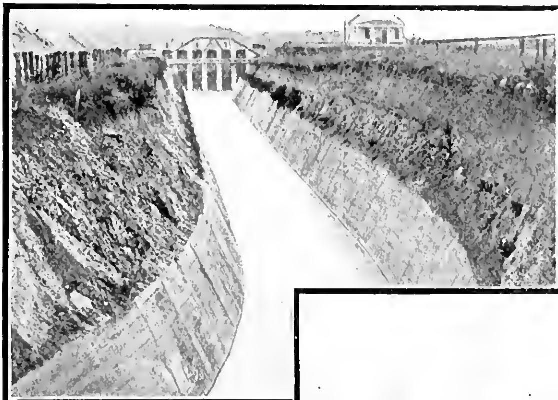


FIG. 179. The head of a canal in an irrigating system.
FIG. 180. An irrigated potato field in Colorado.

In the United States, the government has organized a Reclamation Service to construct irrigation dams and build reservoirs to overcome the effects on agriculture of the little rainfall received by the western highlands. Water is obtained from mountain streams and

led into great canal systems which supply widely separated farms and orchards. Companies have been organized, and farmers pay for the privilege of using the water as we pay for gas. The railroads are quite willing to advance money to further the scheme. As a result, land has increased often 400 times in value, two and three crops a year are raised instead of one, cities are springing up, and a new rush of settlers has set in. Washington, Oregon, California, Wyoming, Colorado, and Arizona are benefiting vastly from this overcoming of the effects of their climate by irrigation. Ten million acres are now irrigated and 75 million more may possibly be reclaimed.

By means of smudges, and even by using oil stoves burning in orchards at night, man staves off the dangers of light frosts to tender blossoms. He erects snow-sheds over railroad tracks in the West and in Canada at dangerous points liable to avalanche falls. Powerful iron-peaked vessels are built in England to ram through the thick ice on Lake Baikal in Siberia, and in the harbors of northern Asiatic ports like Vladivostok, to permit freighters to enter and leave in the winter months.

Am. Mus. Nat. Hist.

FIG. 181. How helpless man is before nature's forces. A city destroyed by a volcano.

Can Man Change Climate? — We have seen the effects of the Labrador current on our Atlantic climate and of the turning of the Gulf Stream toward Europe. An engineer proposed to Congress the building of an ocean jetty or artificial peninsula stretching 200 miles from Cape Race, Newfoundland, eastward across the continental shelf. The cold Labrador current from the north forced away from

the coast by this, would sink under the Gulf Stream and flow southeastward to cool the West Indies. New England, New Jersey, New York, and Maryland would have the warm climate of Spain and Italy that is natural to their latitude. Icebergs would melt far north, fogs would disappear, and Greenland would become fertile. The British Isles and western Europe would have a warmer climate than they have now, since the Gulf Stream would give up no heat to the Arctic current. The great cost and the uncertainty involved will probably prevent the carrying out of this unique idea, but it is an example of the daring imagination of man. Fifty years ago a Panama canal seemed equally impracticable.

Man and Nature. — The general effect of man's efforts to change his environment is insignificant in comparison with what he cannot change or conquer. The results of centuries of his work are mere scratches on the face of the planet. The forces of nature often remind him of his helplessness. His largest vessel strikes an iceberg and goes down like a rowboat. An earthquake and a fire reduce to ruins the work of years. One sixty-hour storm on the Great Lakes sank three steamers, drove twelve others ashore, and took sixty lives. On the same day six ocean liners reached port several days late, delayed by storms; on one, a huge wave had injured six passengers and wrenched off a ten-ton anchor. Twenty-two inches of snow falling about the same time in Cleveland stalled trains, broke down wires, and brought about a loss of two million dollars. Considering the age of the earth, however, and the brief period man has been here, he has indeed accomplished wonders on the face of the planet in conquering the forces of nature.

INDEX

APPENDIX

DIMENSIONS OF THE EARTH

Polar diameter of the earth	7,899	miles
Equatorial diameter of the earth	7,926	"
Length of the equator	24,902	"
Length of a meridian circle	24,857	"
Average length of a degree of latitude	69	"
Length of a degree of longitude at the equator	69.2	"
" " " " " " 10° north or south	68	"
" " " " " " 20° " " "	65	"
" " " " " " 30° " " "	59	"
" " " " " " 40° " " "	52.3	"
" " " " " " 50° " " "	44.4	"
" " " " " " 60° " " "	34.5	"
" " " " " " 70° " " "	23.6	"
" " " " " " 80° " " "	12	"
" " " " " " 90° " " "	0	"

TOTAL AREA OF EARTH'S SURFACE	**196,907,000**	square	miles
Pacific Ocean	70,000,000	"	"
Atlantic Ocean	34,000,000	"	"
Indian Ocean	28,000,000	"	"
Antarctic Ocean	4,998,000	"	"
Arctic Ocean	4,000,000	"	"
Total Sea	**140,998,000**	"	"

THE CONTINENTS		INHABITANTS	
	Area in Square Miles	Number	Per Sq. Mile
North America	9,431,000	110,000,000	11.56
South America	6,856,000	35,000,000	5.10
Europe	3,842,000	400,000,000	106.54
Asia	17,056,000	900,000,000	52.76
Africa	11,512,000	170,000,000	14.76
Australia	3,456,000	8,000,000	2.31
Polar Lands	3,756,000	300,000	0.07
Total	55,909,000	1,623,300,000	29.03

FACTS ABOUT THE PLANETS

Name	Diameter in Miles	Time of Revolution around the Sun	Distance from the Sun in Millions of Miles
Mercury	3,000	88 days	36
Venus	7,700	225 "	67
Earth	**8,000**	**365¼** "	**93**
Mars	4,500	687 "	1½ times the earth's distance
Jupiter	87,000	12 years	5¼ " " " "
Saturn	73,000	29½ "	9½ " " " "
Uranus	31,000	84 "	20 " " " "
Neptune	35,000	165 "	30 " " " "

TIME DIFFERENCE

Places	When it is 12 O'Clock Noon according to				At	
	Eastern	Central	Mountain	Pacific	London	Paris
	Standard Time in the United States					
It is at						
Amsterdam........Holland	5.20 P. M.	6.20 P. M.	7.20 P. M.	8.20 P. M.	12.20 P. M.	12.10 P. M.
Berlin...........Germany	5.54 P. M.	6.54 P. M.	7.54 P. M.	8.54 P. M.	12.54 P. M.	12.45 P. M.
Bombay.............India	9.51 P. M.	10.51 P. M.	11.51 P. M.	12.51 A. M.	4.51 P. M.	4.42 P. M.
Constantinople......Turkey	6.56 P. M.	7.56 P. M.	8.56 P. M.	9.56 P. M.	1.56 P. M.	1.47 P. M.
Dublin............Ireland	4.35 P. M.	5.35 P. M.	6.35 P. M.	7.35 P. M.	11.35 A. M.	11.26 A. M.
Hamburg........Germany	5.40 P. M.	6.40 P. M.	7.40 P. M.	8.40 P. M.	12.40 P. M.	12.31 P. M.
Hongkong...........China	12.37 A. M.	1.37 A. M.	2.37 A. M.	3.37 A. M.	7.37 P. M.	7.27 P. M.
Honolulu...........Hawaii	6.29 A. M.	7.29 A. M.	8.29 A. M.	9.29 A. M.	1.29 A. M.	1.19 A. M.
Liverpool.........England	4.48 P. M.	5.48 P. M.	6.48 P. M.	7.48 P. M.	11.48 A. M.	11.39 A. M.
London...........England	5.00 P. M.	6.00 P. M.	7.00 P. M.	8.00 P. M.	......	11.51 A. M.
Manila.......Philippine Is.	1.04 A. M.	2.04 A. M.	3.04 A. M.	4.04 A. M.	8.04 P. M.	7.54 P. M.
Paris..............France	5.09 P. M.	6.09 P. M.	7.09 P. M.	8.09 P. M.	12.09 P. M.	......
Rome................Italy	5.50 P. M.	6.50 P. M.	7.50 P. M.	8.50 P. M.	12.50 P. M.	12.41 P. M.
Yokohama..........Japan	2.19 A. M.	3.19 A. M.	4.19 A. M.	5.19 A. M.	9.19 P. M.	9.09 P. M.